RF Project 762647/713729
Final Report
Volume I

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USE OF COMPUTER-AIDED TESTING IN THE INVESTIGATION OF PILOT RESPONSE TO CRITICAL IN-FLIGHT EVENTS

VOLUME I

Thomas H. Rockwell and Walter C. Giffin
Industrial and Systems Engineering

For the Period
April 1, 1981 - September 30, 1982

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Ames Research Center
Moffett Field, California 94035

Grant No. NAG 2-112

December 30, 1982

(NASA-CR-169720) USE OF COMPUTER-AIDED TESTING IN THE INVESTIGATION OF PILOT RESPONSE TO CRITICAL IN-FLIGHT EVENTS, VOLUME 1 Final Report, 1 Apr. 1981 - 30 Sep. 1982 (Ohio State Univ., Columbus.)

N83-16037

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FINAL REPORT

USE OF COMPUTER-AIDED TESTING IN THE INVESTIGATION OF PILOT RESPONSE TO CRITICAL IN-FLIGHT EVENTS

VOLUME I

Supported By

National Aeronautics and Space Administration

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NAG 2-112

The Ohio State University Research Foundation #713729

Principal Investigators:

Thomas H. Rockwell

and

Walter C. Giffin

FOREWORD

This report is prepared in two volumes. Volume I reports the findings of the research. Volume II contains the Appendices to the final report. The appendices contain detailed documentation of the tools used to conduct the research. This includes a sample set of displays presented to subjects during computer aided testing, a set of experimenter instructions necessary to operate and modify the programs and a table of contents on the 1981 Symposium on Aviation Psychology supported by this grant.

ACKNOWLEDGEMENTS

The investigators on this project owe a great debt of gratitude to the students who worked so hard to make the project a success, the pilots who generously offered their time as subjects, the secretarial staff who reduced scrawl to text, and NASA personnel who provided both financial and moral support.

The prime movers on computer program preparation were Jeff Lee and Dave Romer. They were responsible for translating verbal descriptions into computer code. Along the way they invented several novel techniques for dynamic presentations and information exchange. Other graduate students who worked on the project from time to time include Kent Brooks, Mark Thomas and Linda Rings. They aided in subject testing and data interpretation.

The graduate research associates were ably assisted by an outstanding cadre of undergraduate engineering students. At different times during the project Tracy Barber, Kathy Brosch, Mike Romeo and Steve Schoenlein were employed. They organized the data, performed statistical analyses and prepared a myriad of graphs, tables and charts. Project typing was performed by Jean Martens assisted by Linda Parsons and Annie Sears.

We are also indebted to our many friends in the OSU Department of Aviation who offered advice and counsel whenever requested. Professors Jack Eggspheuler, Dick Taylor and Stacy Weislogel were especially helpful. Professor Dick Jensen was the one responsible for the First Symposium on Aviation Psychology supported as part of this project.

We also want to thank Dr. Charles Billings and John Lauber who together with many of their co-workers at NASA Ames offered continuing guidance and encouragement throughout the project.

Finally we want to express our sincerest appreciation to all of our pilot friends who gave their valuable time to participate as subjects in these experiments.

Thomas H. Rockwell
Walter C. Giffin

EXECUTIVE SUMMARY

A critical in-flight event (CIFE) is a situation which is unexpected, unplanned, unanticipated and is perceived by the pilot in command to threaten the safety of the aircraft. The CIFE requires pilot judgement beyond routine decision making or pre-programmed decision structure. The safety of the aircraft depends more on pilot cognitive processes than skilled motor performance.

This research extends the results of earlier research on pilot response to CIFE's by using a computer-aided scenario testing system (CAT). The system makes use of an interactive terminal whereby navigation displays, instrument panel displays and assorted textual material are presented by computer graphics. Communication between subject and computer is accomplished by means of the touch sensitive CRT screen. These programs include biographical data, knowledge survey, a variety of diagnostic scenarios, a destination-diversion scenario, an airport ranking exercise and a combined destination diversion/diagnostic test with dynamic state presentation and control (PLATO-GAT). A complete time history of all data inquiries and responses is maintained for each individual subject tested.

Research Objectives

The objectives of this research were to:

1) Design and implement a computer aided testing device for studying pilot diagnosis and destination-diversion decision making.

2) Develop new scenarios to take advantage of the capabilities of PLATO®.

3) Test a variety of candidate hypotheses concerning the style and substance of pilot resource management.

These objectives grew out of earlier research which focused on

full-mission simulation scenarios in a Singer GAT-1 flight trainer and simple paper and pencil problem scenarios. The overriding consideration throughout all this research has been to apply human factors concepts to pilot information processing and decision making in order to:

a) ascertain the role of pilot background, experience and knowledge in problem diagnosis and decision making; and

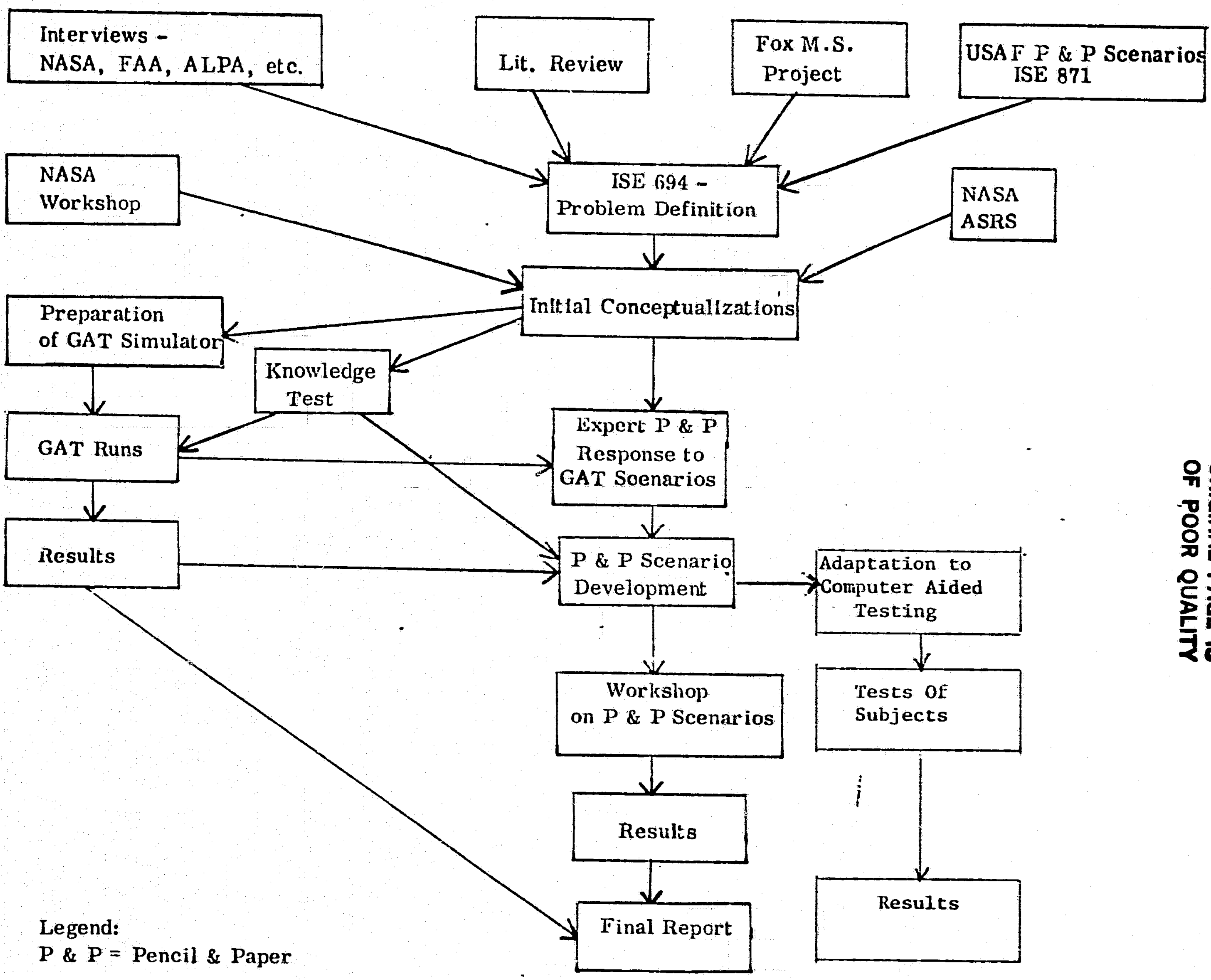
b) describe the problem solving paths in sufficient detail to permit the ultimate development of various models of pilot behavior.

Major milestones in the total project development are noted in Figure 1. The particular tasks accomplished on the current research (CAT) are noted in Figure 2. The Aviation Psychology Symposium, listed as one of those tasks, provided the opportunity to exchange ideas with other researchers in the areas of pilot judgement and decision making.

Computer Aided Testing Formats

Software for a touch sensitive CRT Computer Graphics Terminal has been successfully implemented to perform the biographical questionnaire, knowledge test and problem scenarios previously accomplished by paper and pencil testing. In addition, programs have been written which include dynamic navigation and control capabilities used as part of a full mission simulation embodying both problem diagnosis and destination diversion decisions. A prototype decision support system called Airplane Condition Evaluation (ACE) has also been developed as a computer aid for pilot decision making in emergency situations.

The programs are nearly experimenter free. Communication between subject and computer is accomplished by means of a touch sensitive CRT screen. When results of computer aided testing are compared with the equivalent paper and pencil data, the most striking difference concerns the number of inquiries and information tracks subjects employ.



Legend:
P & P = Pencil & Paper

Figure 1. OSU ISE Department NASA Project Developments

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OVERVIEW OF THE RESEARCH

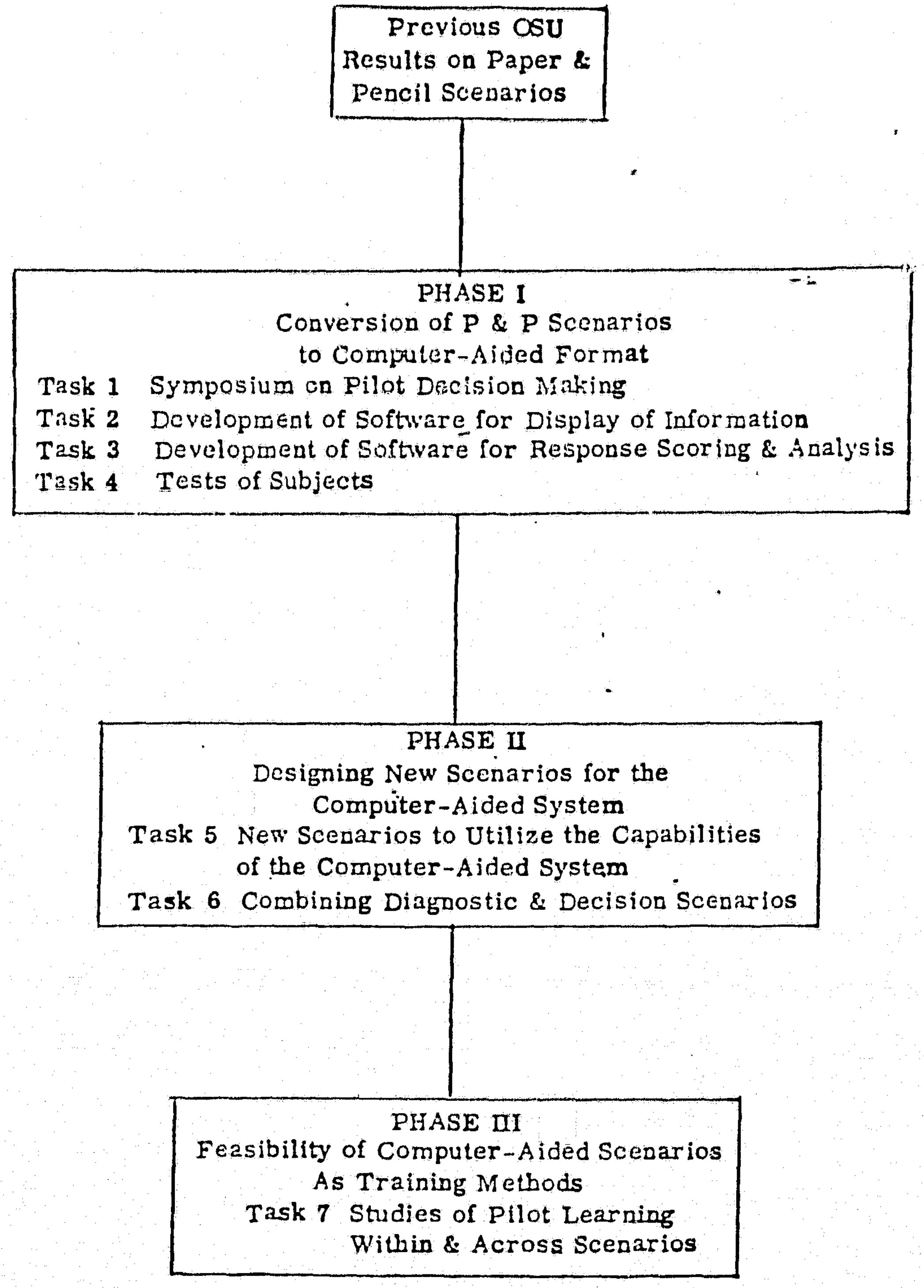

Figure 2: Overview of the Research

In most scenarios the paper and pencil subjects make fewer inquiries and employ fewer tracks than do the CAT subjects. The impersonal nature of communicating with the computer terminal as opposed to the verbal exchange in earlier paper and pencil studies appears to lessen inhibitions and broaden the alternative hypotheses considered by pilot subjects.

Results from CAT

As a result of analyzing the information seeking styles of some 40 subjects using computer aided testing, the following observations can be made:

1) More knowledgeable pilots make better diagnosticians than less knowledgeable ones.

2) Pilots have difficulty in identifying the symptoms of a vacuum pump failure.

3) Knowledgeable pilots reach conclusion (right or wrong) more rapidly than others.

4) Less experienced pilots tend to use a larger number of diagnostic tracks than do more experienced pilots.

5) IFR rated airmen receive higher knowledge scores and higher diagnostic correctness scores than do VFR rated airmen.

6) High correctness scores are positively related to high mean time between inquiries.

7) Pilots follow a wide variety of different search patterns during problem diagnosis.

8) Individual pilots tend to exhibit similar search strategies across different diagnostic scenarios.

9) Efficient information searching can be recognized in particular scenarios and synthesized for general cases.

10) Problem solving schemata are scenario dependent.

11) There is no discernible relationship between the way a pilot collects information for diagnosis and the way he collects information for destination diversion decisions.

12) The only discernible learning effect across scenarios is that time between inquiries is reduced with subsequent trials.

13) Recorded performance measures depend more on the content of the scenario than on its order position within test session.

14) PLATO-GAT subjects exhibit resource management styles similar to those observed in full mission GAT simulations.

15) When faced with both problem diagnosis and the need for destination diversion decision making in the same scenario, pilots show a strong preoccupation with problem symptoms at the expense of positional awareness.

16) Pilots do not keep enroute alternatives in mind in case problems do develop. They react to emergencies more than they pre-plan for emergencies.

17) Data most often requested in diversion decisions are ceiling and visibility. Terrain receives a low number of inquiries.

18) Pilots often neglect available winds aloft information when selecting an alternate airport.

Potential

The computer aided testing instruments described in this report were developed as research tools to be used to better understand the decision making styles of pilots faced with critical in-flight events. However, based on repeated comments by subject pilots these tools may have even greater potential for pilot training. In addition to providing a wealth of potential simulated decision experiences, CAT could be used to uncover pilot deficiencies in their understanding of the nature of CIFE and to help them to develop more efficient search habits. This research can help pilots understand their own problem solving logic structure and hence enable them to reevaluate their approach to diagnosis.

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Chapter 1: Introduction

A. Background

Research concerning pilot and system response to critical in-flight events (CIFE) began in the OSU Department of Industrial and Systems Engineering with NASA contract NAS 2-10047 and was extended under NASA Grant NAG 2-75. Results of those efforts covering the period of October 27, 1978 to February 28, 1981 were reported in "An Investigation Into Pilot and System Response to Critical In-Flight Events" Final Report, Volume I and Volume II, June 1981 (6).

A critical in-flight event (CIFE) is defined as a situation that either develops quickly or over time which is unexpected, unplanned, and unanticipated and which is perceived by the pilot in command to threaten the safety of the aircraft. The CIFE is one which requires pilot judgment beyond routine decision making or preprogrammed decision structure. The safety of the aircraft depends more on pilot cognitive processes than skilled motor performance.

The overall objectives of the early research were to:

(1) Describe and define the scope of the critical in-flight event with emphasis on pilot management of available resources.

(2) Develop detailed scenarios for both full mission and paper and pencil (P/P) testing of pilot response to CIFE's.

(3) Develop statistical relationships among pilot characteristics and observed responses to CIFE's.

These objectives grew out of a concern with anomalies in reported accidents and incidents in which some pilots or crews seemed better able to handle unusual in-flight events than others.

Initial efforts began with a concern for the dynamics of CIFE's and broad attempts to identify pertinent research issues. The final products were: (1) a set of scenarios with associated hardware and techniques for studying CIFE phenomena in a simple flight simulator; (2) a set of paper and pencil scenarios and associated techniques for studying pilot diagnostic strategies and diversion decision making processes; (3) a set of knowledge testing instruments designed to measure a pilot's understanding of aircraft subsystems and troubleshooting; (4) a study relating cockpit crew procedural compliance with performance errors. The result of these efforts were reported in the earlier study by Thomas H. Rockwell and Walter C. Giffin (6).

A five-phase model of pilot CIFE response was hypothesized on the basis of (a) discussions with experts in industry and government and (b) observations made about pilot performance in both simulator and paper/pencil scenarios. The five phases were:

(1) Detection

(2) Diagnosis

(3) Option generation

(4) Decision making

(5) Execution

Pilot information seeking activities permeated all five phases of this process.

GAT-1 Full Mission Simulation

All five phases of pilot response were studied in a GAT-1 flight trainer using the following three full mission scenarios:

(1) Fuel starvation on the active tank (as might be encountered because of a loose fuel cap).

(2) Partial power failure (as might be caused by a broken baffle in a muffler).

(3) Navaid loss (as might be caused by failure of a single airborne receiver component).

A wide range of cockpit management styles and apparent skill levels were observed in these simulations. Although it was difficult to quantify, "good performance" was easily recognized by the observers of the experiment. The elements of "good performance" included:

(1) professional use of the radio

(2) precise heading and altitude control prior to and during the CIFE

(3) constant awareness of the aircraft position along its intended route

(4) prompt, but not instant, response to the onset of the CIFE (detection)

(5) systematic procedure for troubleshooting

(6) knowledge and use of available ATC resources

(7) diversion decisions which allowed for further uncertainties.

In general, it was found that:

(1) Cockpit management style varies widely among pilots. For example, some are extremely self-reliant, others want immediate and extensive help from ATC while still others make the decision making process a joint effort with ATC.

(2) Good stick and rudder pilots seem to have excess capability and maintain good stick and rudder performance during and after the CIFE. More marginal stick and rudder pilots, on the other hand, show increased frequency and amplitude of heading and altitude excursions, and experience communication difficulties in the face of a CIFE.

(3) Pilots who score well on the knowledge test instruments tend to perform well in problem diagnosis and decision making.

Paper and Pencil Experiments

Paper and pencil (P/P) scenarios, and associated experimental techniques, were created to streamline the data collection and analysis for pilot responses to critical in-flight events. Although they lacked the high stress environment of the GAT-1 experiments, these scenarios did yield useful data on the pilot problem diagnosis and decision making strategy phases of pilot response to CIFE's.

Four separate diagnostic problem situations were presented to forty subjects. These scenarios centered about problems presumed to be created by:

(1) an oil leak at the oil-pressure gauge line

(2) a vacuum pump failure

(3) a right magneto drive gear failure

(4) a frozen static port

The decision making phase of the paper and pencil experiments was an alternator failure during an IFR flight which forced a diversion decision on the pilot.

For the information seeking task required in the diversion decision, the pilot was supplied a simplified enroute chart with sixteen airports indicated by letter along his flight path. The subject was then given two minutes to ask for information about any of those airports. For each airport questioned, there were six pieces of information the experimenter was prepared to provide:

(1) bearing and distance from his present location

(2) ceiling at the airport

(3) visibility at the airport

(4) approach aids available

(5) ATC services available

(6) terrain surrounding the airport

The pilot's information seeking observations and ultimate airport selected were recorded.

Later, subjects ranked the suitability of these sixteen potential diversion airports. The worth, or weights, for the variables ATC, weather, time, and approach were obtained by regression analysis according to the techniques of conjoint measurement. This study was reported in Flathers, 1980 (1) and 1982 (2).

The following observations were made from the paper and pencil tests:

(1) There is no correlation between knowledge score and total flight hours.

(2) Knowledge score is correlated with pilot ratings held.

(3) Pilots good in one section of the knowledge survey tend to be good in all sections.

(4) Diagnosis performance is highly correlated with knowledge scores.

(5) Knowledge is inversely related to total number of diagnostic inquiries, e.g., knowledgeable pilots reach conclusions (right or wrong) more rapidly than others.

(6) Total diagnostic inquiries is inversely related to correctness, this implies that undirected experimentation is poor diagnosis style.

(7) Total diagnosis correctness score is correlated with efficiency, i.e., the ability to arrive at a diagnosis with a minimum number of inquiries.

(8) Civil trained pilots place a higher worth on ATC service in diversion decisions than do military pilots.

(9) Private pilots place a higher worth on weather factors in diversion decisions than do commercial and ATP rated pilots.

(10) ATP rated pilots place high worth on time in diversion decisions.

(11) Pilots with good diagnostic scores place less weight on approach aids in diversion decisions.

(12) Pilots with good diagnostic scores place more weight on time in diversion decisions.

(13) The pilots with good diagnostic performance were characterized as knowledgeable about aircraft systems, employed few tracks (a track represents a coherent line of questions, e.g., fuel systems), used few inquiries per track, and emphasized time in their destination diversion decisions.

B. Research Objectives

The major objective of the current research was to extend the effectiveness of past pilot diagnostic and decision testing through the use of computer interactive terminals employing existing software. Such interactive terminal systems provided the researcher with: (1) display graphics (e.g., segments of instrument panels with moving indicators), (2) real-time capability to allow timing of response elements, (3) rapid analysis of pilot inputs and (4) positive and/or negative feedback of results as a special experiment. Subject interactions with aircraft controls and displays were programmed as well as communication with ATC by selecting information requirements from an array ("menu") of information sources available.

The research plan entailed three major research phases embodying seven research tasks as shown in Figure 1-1. All of these tasks except Task 1 are detailed in the chapters to follow. Task 1, the symposium on pilot decision making, has been reported separately in Proceedings for the First International Symposium on Aviation Psychology (4). A table of contents for the proceedings is reproduced in Appendix G of Volume II of this report.

OVERVIEW OF THE RESEARCH

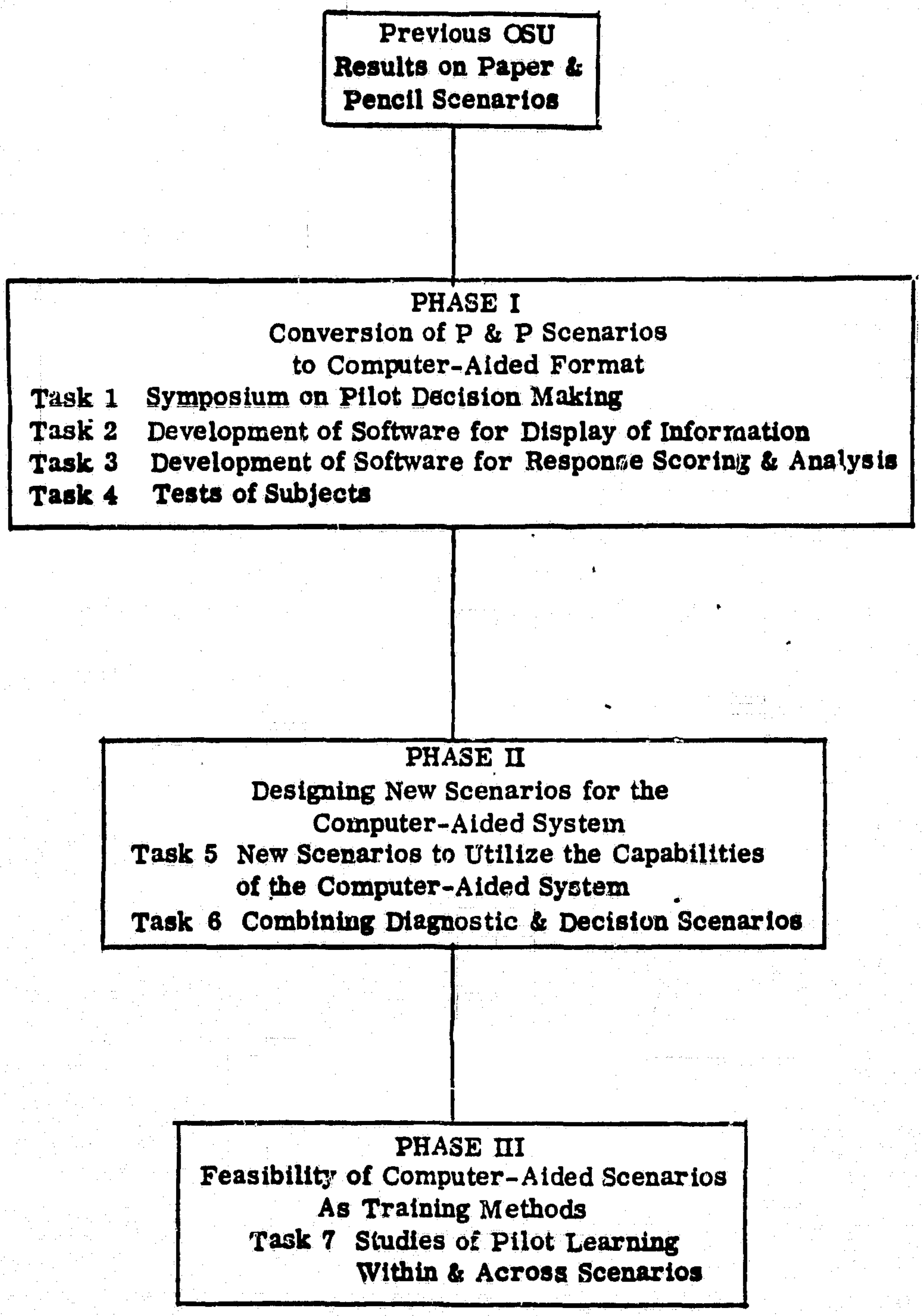

Figure 1-1

Chapter II: Development of Computer Aided Formats

The major task in this research was to design and implement a computer aided testing device for studying pilot diagnosis and destination-diversion decision making. The initial software for the computer graphics terminal was designed around the problem scenarios, knowledge test, and biographical questionnaire used in previous paper and pencil studies (Tasks 2 and 3 of the project proposal). Some new diagnostic scenarios were also designed to take advantage of the capabilities of PLATO® (Task 5). In addition, both diagnostic and destination diversion scenarios were combined into a single scenario with added workload (Task 6).

A. Program Design

Appendices A to E in Volume II of this report include sample displays presented to the subject in the course of testing. The CIFE data collection/subject testing system was built using CDC's PLATO® system and the TUTOR programming language. Details on the various programming modules are discussed in Appendix F.

The goal was to produce a set of programs which could be nearly experimenter-free. Considerable effort was expended to provide the subject with detailed instructions via the graphics display on exactly what tasks were expected of him. After an initial sign-on via the terminal keyboard, all subsequent communication between subject and computer was accomplished by means of the touch sensitive CRT screen. The major elements of the program displayed for the subject included:

(1) CIFE Router

(2) Biographical Data

(3) Knowledge Test

(4) Six Diagnostic Scenarios

(5) The Destination/Diversion Scenario

(6) The Airport Ranking Exercise

(7) VOR-Autopilot

(8) Combined Destination Diversion and Diagnostic Scenario Test (PGCIFE)

(9) Data Display

Router

The CIFE Router is the main program module which allows access to all other modules and to the data files. The router is accessed by a special student sign-on to the PLATO® system. At the completion of each separate program module, control is returned to the Router where the subject may select the next module by touching the appropriate place on the CRT screen.

Biographical Data

The first time a subject uses the program he is assigned a unique subject identification number and is forced to enter the Biographical Data module in order to establish a subject data file. If testing is interrupted for any reason, the same subject number will permit access to any module without again going through the Biographical Data module. All biographical data are displayed in the form of multiple choice questions to which the subject responds by touch panel. A sample of biographical data questions is contained in Appendix A.

Knowledge Test

The Knowledge Test module presents a series of twenty multiple choice questions one at a time. These questions cover three subcategories: (1) Engine and Fuel Systems, (2) Electrical Systems and Cockpit Instrumentation, and (3) Weather and IFR Operations. The Knowledge Test displays are contained in Appendix A.

B. Diagnostic Scenario Operations

In each of the diagnostic scenarios the subject is told that he is flying a Piper Cherokee Arrow and is given a list of equipment and performance parameters. The next display is then a brief paragraph which describes his mission and the symptoms of a problem being encountered. The subject then has a fixed amount of time (usually four minutes) in which to seek information and arrive at a diagnosis of the problem. Information is available from four separate displays which can be called up by the subject at any time during his allotted test period. He is not penalized for the time required to paint a new display on the screen.

The information displays include: .

(1) instrument panel

(2) interior information

(3) exterior information

(4) ATC information

The instrument panel display contains most of the instruments and controls found in a Cherokee Arrow. Information is obtained by touching the appropriate dial or control. If, for example, a subject wants to know his oil pressure reading, he touches the oil

pressure gauge, shown graphically on the panel layout, and its current status is printed for him in the display area. It is also possible to obtain information concerning control movement. For example, if the subject touches the prop rpm, a secondary input display permitting him to increase or decrease rpm appears. If he touches either of those boxes, an appropriate response message is then printed. The instrument panel display is shown in Appendix A.

The three remaining information displays all work alike. A subject touches the box containing desired information and a description of that information is printed out for him. Interior information refers to inside cabin conditions. This display permits one to find out about smoke, fluid leaks, unusual sounds, etc. which may be in the cockpit. Exterior information includes such things as cowling condition, wing condition, etc. A query on wing condition for example might bring forth a response "light rime ice visible". ATC information includes general weather and navigation aid status information of the type that a Flight Service Station or Air Route Traffic Control Center might provide. These data include such items as forecast winds aloft and freezing levels. All three displays, interior, exterior and ATC information, are shown in Appendix A.

When the subject reaches a conclusion concerning the cause of the problem (or he runs out of allotted time), he pushes the "give answer" choice available with each of the information displays. This action routes him to a second choice menu which permits him to seek further information in the event that he inadvertently or

prematurely pushed "give answer". A second push of "give answer" then routes him to the lexicon illustrated in Appendix A. The subject formulates his diagnosis by touch panel entry designating up to nine of the words listed in the lexicon.

After entering his lexicon response the subject is asked a series of questions concerning his judgment of the problem. The computer asks for an estimate of how long the plane will fly with its existing problem, how critical (scale 1 to 7) the problem is, and how confident the subject is in his own diagnosis.

At that point the problem around which the scenario was designed is presented to the subject as the correct diagnosis. He then is again asked to respond to the time and criticality questions in light of his now complete knowledge of the state of his aircraft systems. Control then passes back to the router where a new scenario or other task can be selected.

A complete time history of all subject data inquiries is maintained for each individual subject tested. The particular display and the item on that display which was queried are noted together with the time since initiation of that scenario at which the query took place. This time history of information search is available through the Data Display module.

C. Diagnostic Scenario Content

Diagnostic scenarios one through four are adaptations of scenarios previously used in paper and pencil testing. (See project report NAS2-10047 (6)). They concern: (1) an oil pressure gauge line break, (2) a vacuum pump failure, (3) a broken magneto drive gear, and (4) a blocked static port.

Two new scenarios were created to accomplish certain computer aided testing objectives which were not part of the earlier paper and pencil tests. Scenario five is a nearly no-win situation. The problem is manifested by a partial power loss which no amount of cockpit experimentation can correct or even totally identify. The power loss is assumed to be caused by a broken baffle in the muffler which creates a horsepower robbing backpressure in the exhaust system. This scenario is designed to explore a subject's information search patterns while eliminating the possibility of accidently uncovering the key element of information which uniquely identifies each of the four earlier scenarios. Scenario five also forms the diagnostic portion of the combined destination diversion and diagnostic search task to be described later.

Scenario six is designed to present symptoms which might be improperly attributed to a mechanical failure when in fact a non-mechanical act has caused the problem. This scenario concerns an upholstery fire caused by a carelessly discarded cigarette.

The complete text of each scenario and the proper diagnosis as presented to the subject are reproduced below and in Appendix B.

Diagnostic Scenario One

You are making a day trip from Albany, NY to Burlington, VT. You fly out of Albany at 9:00am, cleared Victor-91, Burlington. You climb to a cruising altitude of 7000ft. After 20 minutes of routine IMC flying you notice the smell of engine oil.

How would you diagnose the problem?

Our diagnosis ~~of~~ the problem was the following:

A small crack developed in the oil line feeding the oil pressure gauge. This crack reduced the oil pressure reading drastically, but did not seriously affect the actual lubrication of the engine. A small pool of oil began to form on the floor of the cabin, pilot's side. Assuming that the cracked line would not deteriorate quickly into a complete break, you were in no immediate danger of engine seizure.

Diagnostic Scenario 2

You are making a day trip from Augusta,ME to Lebanon,NH..You fly out of Augusta at 9:ØØ am,cleared Victor 39 to Meets intersection, Victor 496 to Lebanon.You climb to a cruising altitude of 6ØØØ ft.After 15 minutes of routine IMC flying in instrument conditions,your instruments indicate an increase in airspeed and steadily decreasing altitude while maintaining level flight attitude.

How would you diagnose the problem?

Our diagnosis of the problem was the following:

Your vacuum pump failed as indicated by the low reading of the suction gauge. The vacuum pump drives the attitude and directional gyros.As the artificial horizon lost its drive it started to sag to the right and you compensated by turning left,leveling the artificial horizon and putting the plane in a slow, descending left bank.The airspeed increase was due to the slight nose-down attitude.

Diagnostic Scenario 3

You are making a day trip from Keene, NH to Montpelier, VT. You fly out of Keene at 10:30 am, cleared Victor-151 to Montpelier. You climb to a cruising altitude of 5000 ft. After 20 minutes of routine cruise in IMC your engine suddenly starts running extremely rough, shaking the whole plane and losing about 20% of its cruise power.

How would you diagnose the problem?

Our diagnosis of the problem was the following:

Your engine suffered a broken drive gear in the right magneto. The resultant untimed ignition conflicted with the remaining good ignition and caused the extremely rough engine and backfiring. Switching from 'both' to the left magneto would have resulted in a smooth running engine with slightly less power than normal cruise.

Diagnostic Scenario 4

You are making a day trip from Sanford, ME to Messena, NY. You fly out of Sanford at 8:30am, cleared Victor-496 to Lebanon, Victor-141 to Messena You climb to a cruise altitude of 6000. After 20 min IMC flying, Boston Center instructs you to climb and maintain 10,000ft. You acknowledge and begin your climb between layers. After 2 min of climb, you notice your indicated airspeed dropping off steadily from 100kts, maintaining constant pitch attitude.

How would you diagnose the problem?

Our diagnosis of the problem was the following:

As you climbed through 6500ft, the static port froze over as the outside air temperature dropped below 32°F. This caused the airspeed indicator to decrease as altitude increased and the VSI and altimeter to read low. Several corrective actions were possible: return to your previous altitude of 6000ft; open the alternate static source; break the VSI glass.

Diagnostic Scenario 5

You are making a day trip from Augusta,ME to Lebanon,NH. You fly out of Augusta at 10am, cleared Victor 39 to Neets Intersection, Victor 496 to Lebanon. You climb to a crusing altitude of 8000ft. After 20 minutes of routine flying in instrument conditions with light to moderate turbulence, you notice that increased nose-up trim is required to maintain a constant indicated altitude and that your IAS has decreased 20kts from normal cruise.

How would you diagnose the problem?

Our diagnosis of the problem was the following:

A baffle was broken in the muffler. The broken baffle partially blocked the exhaust system causing increased exhaust backpressure. The increased exhaust backpressure absorbed a portion of the available horsepower output from the engine. With a constant throttle setting, the prop flattened pitch to maintain constant RPM causing a decrease in airspeed while altitude was held constant. Conversely when airspeed was held constant altitude decreased due to reduced power output available at the propeller. Increasing the manifold pressure with added throttle permitted enough power to be developed to maintain altitude at a greatly reduced airspeed.

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Diagnostic Scenario 6

you are making a day trip from Montpelier.VT to Bangor.ME with two passengers on board. You fly out of Montpelier at 1:00pm, cleared radar vectors to Wylie intersection, direct Augusta, Victor 3 to Bangor. You climb to a cruising altitude of 9000ft. After 30 minutes of routine flying in instrument conditions with light to moderate turbulence, one of your passengers reports smelling a faint burning odor. You are unable to detect the odor because you have a head cold.

What is the first thing you would do?

Our diagnosis of the problem was the following:

Rear seat carpeting was smoldering. The rear seat passenger lit a cigarette shortly after takeoff. When he disposed of it in the ashtray, it was not completely extinguished. The cigarette fell down from the ashtray and was beginning to char upholstery material. The fire was easily extinguished, once recognized and posed no immediate danger to the flight.

D. <u>The Destination Diversion Scenario</u>

The destination diversion scenario was also an adaptation of an earlier scenario used in paper and pencil tests. The goal was to examine the information seeking activities and decision making strategy of subjects forced to make an enroute diversion decision.

The subject is presented with a business trip scenario involving an IFR flight from Bangor, Maine to Glens Falls, New York in a Piper Cherokee Arrow. Area weather charts, a Flight Service Station briefing and a flight plan are presented in turn as the scenario begins. Once the flight is underway, a simplified low altitude enroute chart is shown on the graphics display. A flashing arrow on that chart depicts the progress of the flight as the scenario continues to depict flight progress along the intended path. At a point midway along the planned flight the subject is told that he has experienced an alternator failure and must now operate on battery power alone. The maximum expected life of the battery is insufficient to carry him on to his planned destination. The problem now is to select a suitable alternate airport.

Alternate airports are depicted by number on a further simplified enroute chart. The subject may ask for up to six items of information about any of the sixteen airports depicted on the chart:

(1) bearing and distance

(2) ceiling

(3) visibility

(4) approach aids

(5) ATC services

(6) terrain

He has two minutes in which to conduct his information search and select an alternate airport. A summary display of all information requested is available to the subject anytime he wishes to examine it.

A complete time history of his information search is maintained in the computer data file along with his final choice of airport. A complete set of graphics displays shown to the subject during testing is shown in Appendix D. A sample of the stored data is contained in Appendix C.

Airport Ranking

As an alternative way of studying the diversion decision, an airport ranking exercise was created. The ranking exercise was the alternator failure scenario previously discussed. This module accomplishes the same thing by way of computer graphics that was previously accomplished by shuffling cards in the paper and pencil studies.

Here the subject is presented with a matrix of information involving sixteen possible diversion airports. Each airport is listed together with its ATC services, ceiling, visibility, time to reach and approach aids. The subject ranks these airports from most desirable to least desirable. All entries are made by touch panel. The matrix is updated with each ranking decision by interchanging rows, replacing the current occupant in decision row x with the occupant the subject would prefer while moving the

old occupant in x to the position vacated by the new choice. The displays used in this module are shown in Appendix D.

E. VOR-Autopilot

The VOR-autopilot module is a training module designed to instruct a subject on the use of the dynamic navigation and control capabilities he will later use in the combined destination diversion and diagnostic scenarios. The basic control display is shown in Appendix E.

By appropriate touch panel entry a subject can select desired heading and altitude commands for his aircraft autopilot. If the command heading is not the one currently displayed on the directional gyro, the simulated aircraft will begin a standard rate turn toward that heading. If the altitude selected is not that currently stored in the instrument panel display, the simulated aircraft will begin a pre-programmed rate of climb (or descent). At the same time that instrument indications are being updated, the simulated aircraft continues to move through space. That movement is reflected by the tunable VOR heads contained on the display.

The subject can determine his current position in space by selecting appropriate VOR frequencies and centering the needles. The admissable VOR's are depicted on an accompanying simplified low altitude chart.

Each subject is given a few brief training exercises involving turns to heading and locating the aircraft relative to VOR stations. This training exercise does not refer to any particular problem scenario but rather is intended to familiarize him with the new dynamic system.

F. Combining Destination Diversion With Diagnosis

The combined scenario described in Figure 2-1 was designed to meet two purposes:

(1) It was a "no win" problem, i.e. no pilot would really be able to find the true cause from the symptoms presented. Hence, it would avoid a pilot stumbling into the key information item and force the pilot to examine all possible hypotheses. The diagnosis portion was the same problem previously discussed as scenario #5.

(2) It combined on the touch CRT both the destination diversion decision and the problem of diagnosis.

Appendix E shows the displays used in this scenario. This includes a simulated low altitude chart. A program has been developed for PLATO® which locates the aircraft relative to the VOR site, allows heading changes and allows the position of the aircraft to be determined from VOR radials as the aircraft moves at some selected speed and heading. It should be noted that attempts to develop positional awareness are used throughout. These include position reports to ATC based on dual VOR's location assessment, auto pilot heading change requirements, new clearances and even a concerned passenger requesting a return to the departure airport. This scenario employs some dynamics, i.e. loss of altitude with neutral forces on the yoke and attendant changes in VSI and airspeed with control inputs. As the flight progresses the VOR needle shows a deflection. The scenario permits communication with ATC and allows for declaring emergencies.

Consult attached simplified altitude chart.

You are on an IFR flight from Utah Municipal Airport to Haven Count Airport. You depart on V-110 at 6000 ft. in your Cherokee Arrow (N123B) which is equipped with a 3-axis autopilot. There is a NOTAM out which reports that Colorado VOR is out of service during the period you plan to navigate. Navigate using Ohigh and California VORs. You have been enroute 60 minutes from Utah Municipal Airport. You are on the gauges but the ride is smooth. Weather briefing indicated that winds at 6000 were expected to be light and variable.

You have one passenger aboard.

Weather at:

Haven County Airport = 2000 & 5
Ohigh = 1000 & 3
Wind Falls = 1000 & 3 by a C-172
(10 Minutes Ago)

Cleve Center calls and reports radar contact is lost. Please report present condition.

Clearance

ATC Response:

N123B, thanks for the position report.
Here is your new clearance:
proceed direct California VOR direct
Haven County Airport at 6000.

There will be opposite traffic at 5000 . . . maintain 6000.

Please confirm your new heading and altitude after your turn.

Scenario Change

While practicing hand flying with your autopilot disengaged, you notice that increased nose-up trim is required to maintain a constant indicated altitude and that your IAS has decreased 20 kts. from normal cruise.

Your passenger notes this problem, and suggests that you turn back to Utah Municipal.

Determine the nature of the problem, and your destination decision.

Figure 2-1: Combined Diagnosis and Destination Diversion Scenario

The purpose in combining diagnosis and destination diversion problems into a single scenario was outlined in Task 6 of the original proposal. The combined scenario was created to provide a more realistic framework for tests which would begin to approach the fidelity of the earlier GAT simulations, in the sense of dynamic position information and added workload. The research question was whether PLATO® lends itself well to simultaneous navigation and diagnosis even though no control manipulation skills beyond selection of heading and altitude commands were possible.

Chapter III: Results of Computer Aided Testing

Two types of analyses were made based on the data generated through computer aided testing. The first type of analysis was based on the power of the computer to generate a variety of summary statistics. Here such standard techniques as regression analysis, t-tests, chi-square tests and frequency counts were used on a variety of different combinations of subject data. The intent was to isolate important performance measures and classify groups of subjects.

The second type of analysis required the generation of creative graphical aids which permit a particular subject's information seeking strategy to be absorbed at a glance. By comparing performance across subjects it became possible to identify several distinct search strategies which were not apparent from the more formal statistical tests. The graphical aids used to depict information seeking behavior during diagnosis testing were the pilot information plot (PIP) and schema diagrams. The aid used to depict the destination diversion information search was the destination information graph (DIG).

A. Depiction of Diagnostic Information Seeking Patterns For Individual Subjects

Figures 3-2 through 3-5 depict a way to view subject information seeking patterns during diagnosis testing. Sources within logic tracks are identified for each scenario. The pilot information plots (PIP's) are a quick way to visualize:

(a) the number of tracks* employed

(b) the order of inquiries within and between tracks

(c) the time between inquiries

(d) the number of track returns and the information resampled

Using these PIP's various information seeking strategies can be observed. For the suction failure problem as shown in Figure 3-1, Figure 3-2 depicts a subject with a logical and efficient approach to diagnosis. Figure 3-3 depicts an almost random inquiry which leads to no logical conclusion. For most scenarios there is a key element or piece of information to identify the problem, e.g. low suction and vacuum failure. Figure 3-4 shows a subject with the key piece of information but who still does not recognize the correct answer. Figure 3-5 clearly indicates a subject using a systematic approach but an incorrect one. In this case the subject believes ice to be the causal factor for the symptoms presented.

Based on PIP analyses, idealized information searching can be hypothesized. The ideal pilot first confirms the symptoms given him. He then establishes whether his engine status is threatened by whatever cause lies behind the symptoms. Usually oil temperature and pressure and manifold pressure suffice to test this condition. Next he makes two or more hypotheses as to the cause, and makes a determination of the plausibility of these hypotheses with a minimal number of inquiries within the appropriate tracks. He rarely needs to go over old logic tracks sampled. Finally, given a logical cause of the symptoms (usually from the key information element), he will often make sure alternative hypotheses are still not viable by additional information inquiries.

---

*a track is a coherent line of questioning focused on an aircraft subsystem, e.g., internal engine condition.

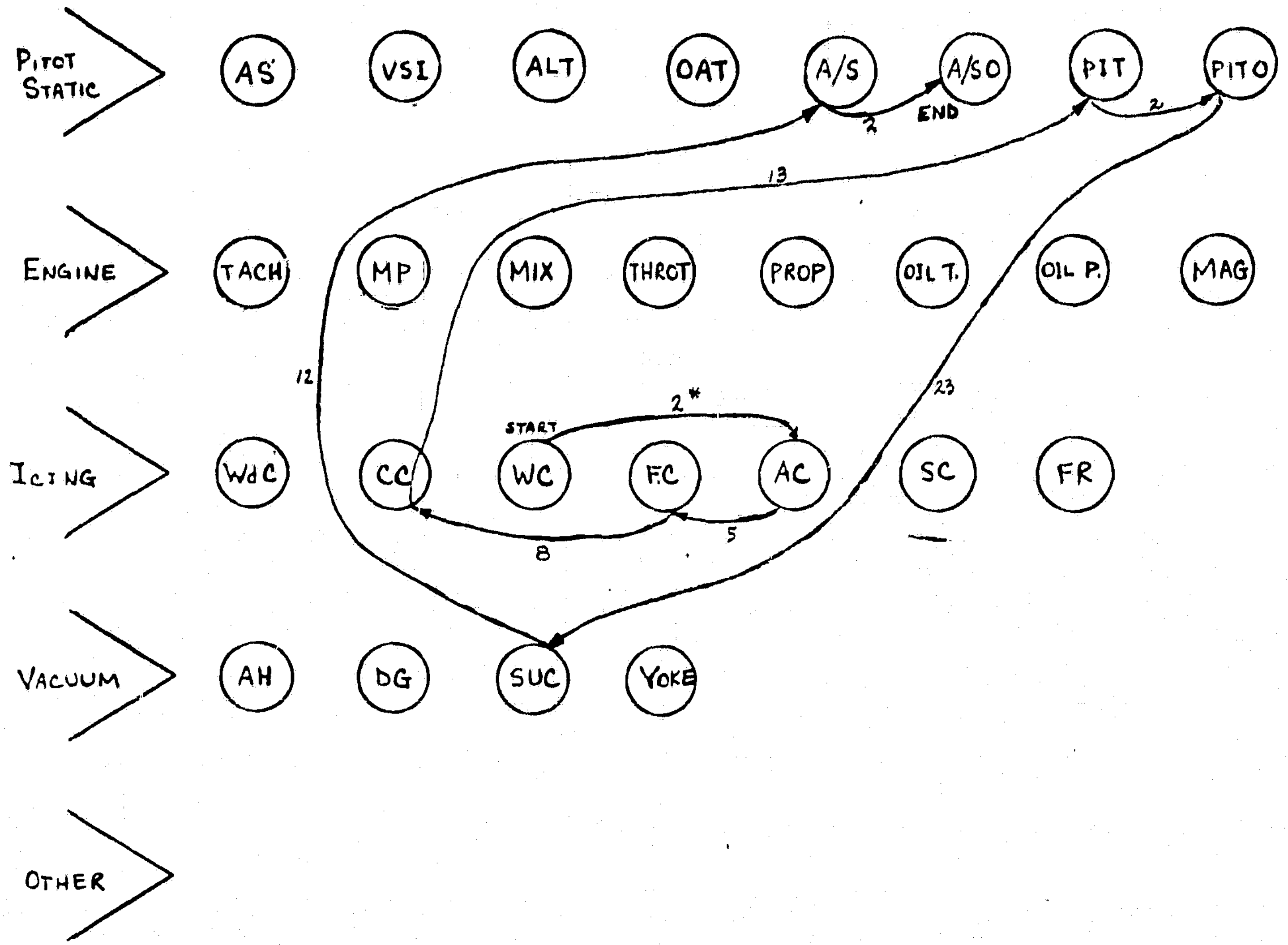
SCENARIO

You are making a day trip from Augusta, ME to Lebanon, NH. You fly out of Augusta at 9:00 a.m., cleared Victor 39 to Neets intersection, Victor 496 to Lebanon. You climb to a cruising altitude of 6000 ft. After 15 minutes of routine IMC flying in instrument conditions, your instruments indicate an increase in airspeed and steadily decreasing altitude while maintaining level flight attitude. How would you identify your problem?

Our Diagnosis of the Problem was the Following:

Your vacuum pump failed as indicated by the low reading of the suction gauge. The vacuum pump drives the attitude and directional gyros. As the artificial horizon lost its drive it started to sag to the right and you compensated by turning left, leveling the artificial horizon and putting the plane in a slow, descending left bank. The airspeed increase was due to the slight nose-down attitude.

Figure 3-1: Suction Failure Problem and Diagnosis



RESPONSE: Gyro Broken

CONFIDENCE IN RESPONSE: 7

CRITICALITY: 5

TOTAL FLIGHT TIME: 100-300 Hrs.

TOTAL DIAGNOSIS TIME: 78 Sec.

RATING: Private - VFR

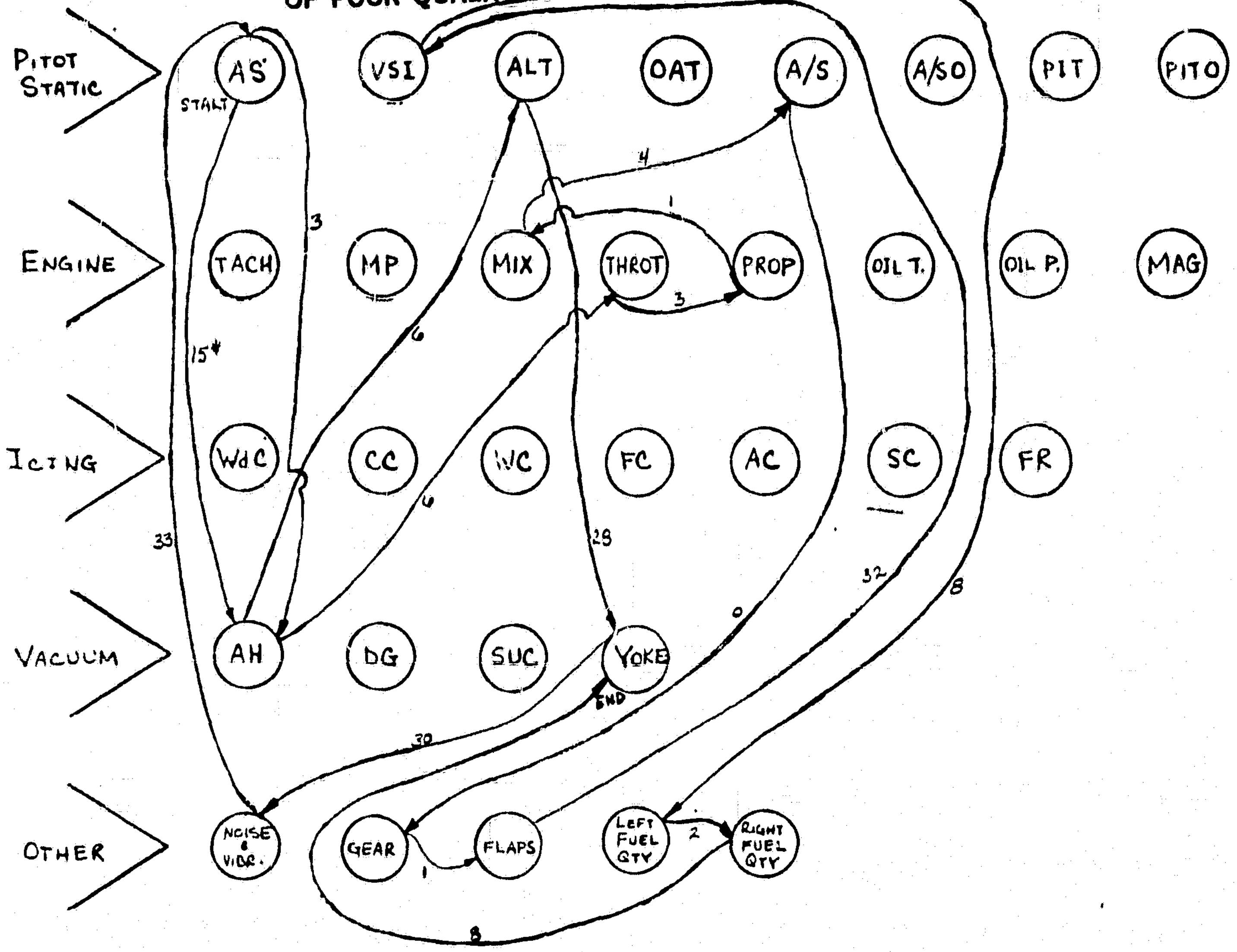
KEY TERM: N Y

TOTAL NO. INQUIRIES: 9

KNOWLEDGE SCORE: 60%

*Time Between Inquiries

Figure 3-2. Pilot Information Plot For Scenario #2 Subject #53



RESPONSE: Elevator Control Pressure

CONFIDENCE IN RESPONSE: 7

CRITICALITY: 1

TOTAL FLIGHT TIME: 100 Hrs.

TOTAL DIAGNOSIS TIME: 211 Sec.

RATING: Private - VFR

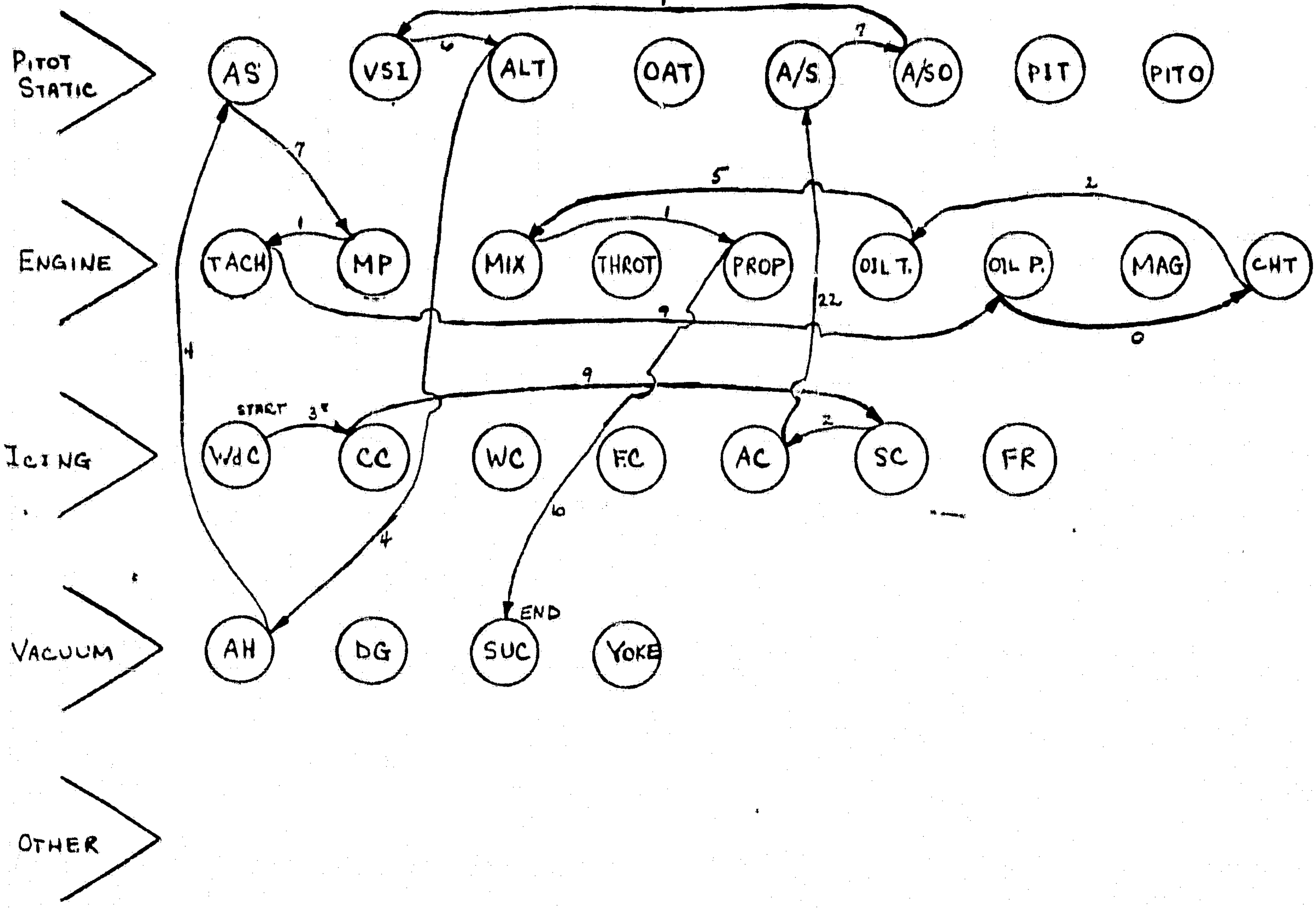
KEY TERM: N Y

TOTAL NO. INQUIRIES: 20

KNOWLEDGE SCORE: 50%

*Time Between Inquiries

Figure 3-3. PILOT INFORMATION PILOT FOR SCENARIO #2 SUBJECT #67



RESPONSE: Pitot Ice

CONFIDENCE IN RESPONSE: 6

CRITICALITY: 3

TOTAL FLIGHT TIME: 501-1000 Hrs.

TOTAL DIAGNOSIS TIME: 127 Sec.

RATING: Commercial-IFR

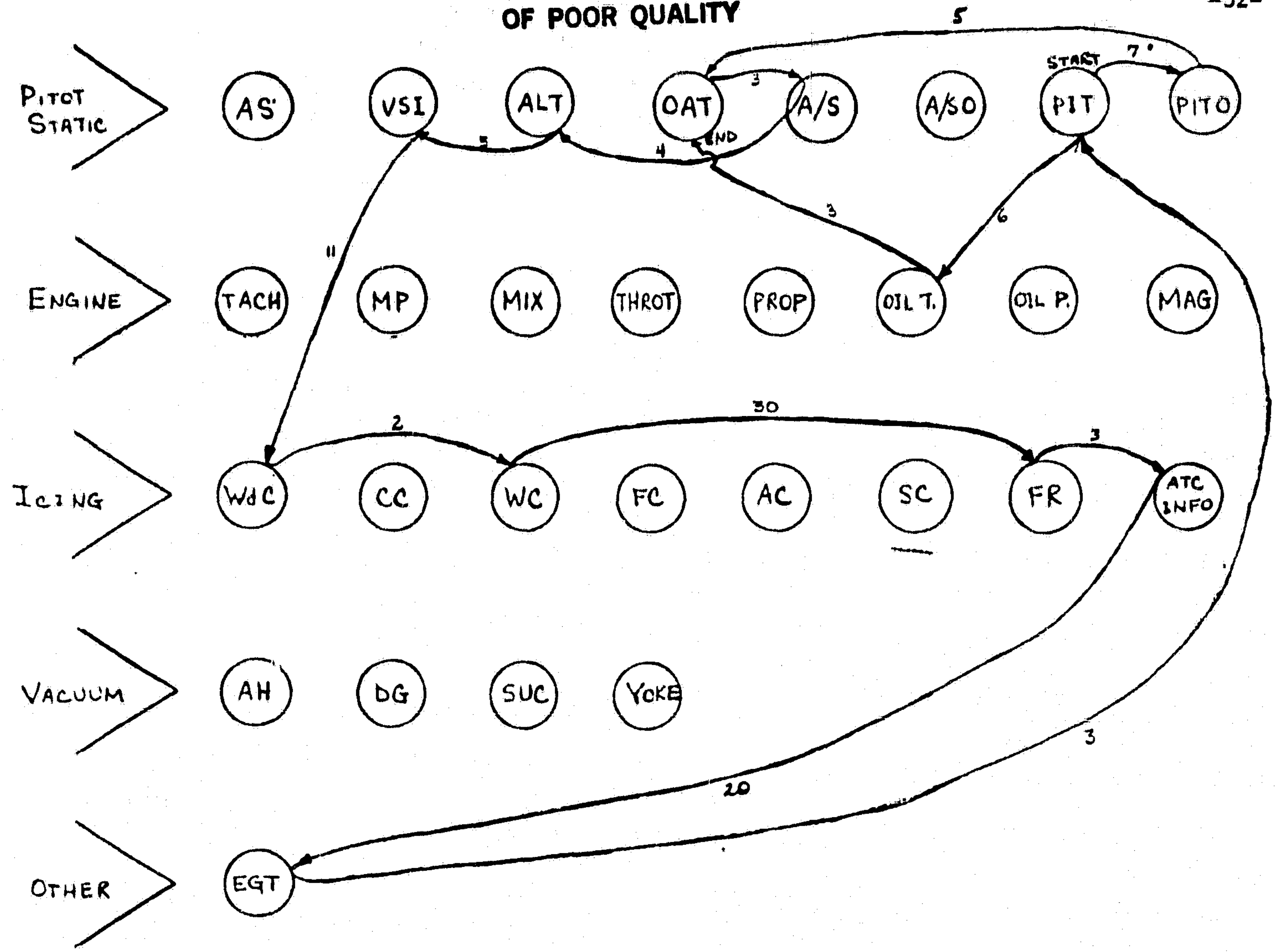
KEY TERM: N Y

TOTAL NO. INQUIRIES: 19

KNOWLEDGE SCORE: 50%

*Time Between Inquiries

Figure 3-4. Pilot Information Plot For Scenario #2 Subject #55



RESPONSE: Pitot Static Prop Ice

CONFIDENCE IN RESPONSE: 6

CRITICALITY: 6

TOTAL FLIGHT TIME: 501-1000 Hrs.

TOTAL DIAGNOSIS TIME: 123 Sec.

RATING: Commercial-IFR

KEY TERM: N Y

TOTAL NO. INQUIRIES: 16

KNOWLEDGE SCORE: 40%

*Time Between Inquiries

Figure 3-5. Pilot Information Plot For Scenario #2 Subject #54

B. Summarizing Diagnostic Information Search Patterns Graphically

Schema theory provides a method for investigating the underlying logical structure (schema) which provides a mental outline by which a pilot may organize information. A pilot has some knowledge of the events that typically occur in a critical in-flight event and the order in which they take place. The completeness of his knowledge will determine the ease with which he can comprehend and summarize diagnostic information. By separating "correct" diagnoses from "incorrect" diagnoses one may be able to develop guidelines from schemata which highlight efficient information search strategies.

The schema diagrams developed for this research plot each item of information sought by the frequency with which it is requested and the median order percentile in which that item appears in the total stream of information requests. The technique is patterned after that discussed by Geiselman and Samet (3).

For example, on scenario 1 subject 64 asked for 26 separate items of information over a period of 205 seconds. Cylinder head temperature was the third item of information sought and that was requested at 8 seconds into his search. In terms of order, this information was in the 11.5 percentile order position and the 3.9 percentile time position. By performing similar calculations for each subject it was determined that 90 percent of the subjects in scenario 1 with the correct diagnosis asked for cylinder head temperature (CHT), that the median order percentile for their requests was 34.5. These data were then plotted on two schemata, one

showing frequency versus order and the second showing frequency versus time.

By grouping items of information into common subject matter clusters, it is possible to develop a two-dimensional hierarchical outline of subordination and sequential order of information. Level of subordination is measured by the percent of pilots who include that information in their search. Output position is standardized by computing a median output position percentile for each item of information which was sought by at least one subject.

Figure 3-6 shows a schema diagram for successful subjects on the first scenario. This scenario involved a cracked oil pressure gauge line behind the instrument panel. Positive confirmation of the problem was possible by noting the reduced oil pressure and the presence of fluid leaks in the cockpit. Roughly 90 percent of the subjects included oil pressure, oil temperature, cylinder head temperature and fluid leaks in their search, although fluid leaks did show up late in the order of information (cluster 1 on the schema diagram). Another sizeable portion, 60 percent, appear to be searching for evidence of an oil system failure in front of the firewall (cluster 2). A much smaller minority of approximately 10 percent appear to be concerned about general engine health (cluster 3). The information in cluster 4 which appears late in the search process for some of the subjects seems to be directed toward localizing the source of the smell of hot engine oil, e.g. is it in or outside of the cabin. Note that even though all of the

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Subjects: 42, 43, 46, 47, 51, 52, 53, 54, 55, 56, 57, 59, 60, 61, 64, 67, 68, 80

Frequency (%) vs. Order (Median)

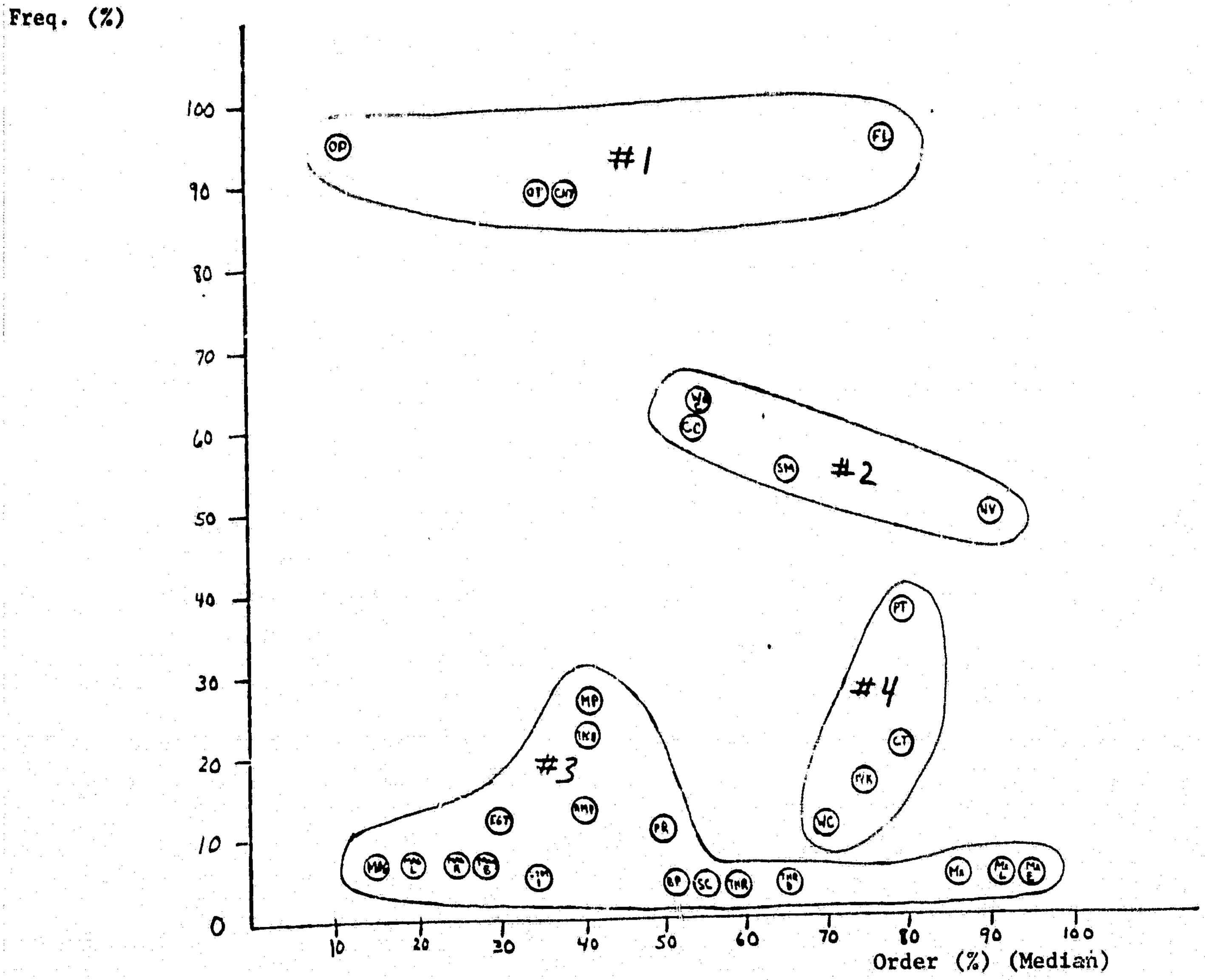

Figure 3-6: Schema For Subjects In Scenario #1 With Correct Diagnosis
(See Figure 3-21 for the list of symbols used in schemata on Page 89)

subjects in this schema solved the problem, the median percentile position for the key item "fluid leaks" was only 78. Evidently many sought further confirmation even after having the key. As identified earlier this is an example of pilots checking on alternative hypotheses.

C. Grading Diagnostic Results

Correctness scores, which were used to measure a subject's diagnostic performance, were related to a simple five point scale. Each of the four basic scenarios could have been unambiguously diagnosed if the subject asked for a certain key piece of information. For example, in the oil pressure gauge line leak scenario the key element was "fluid leaks". In the vacuum pump failure scenario the key element was "suction". In the magneto gear failure scenario the key element was "left mag". In the static port icing scenario the key element was "alternate static source". Correct answers were awarded a grade of five, four, or one, depending upon whether the key element was asked for, whether the subject was on the right track or whether there was no apparent connection between the information sought and the correct response.

Incorrect answers which could at least be partially supported from a logical search pattern were given two points. Incorrect and illogical searches were graded zero. This scheme is summarized in the table below.

Table 3-1. Diagnostic Scoring

Conclusion / Information	Correct Answer	Incorrect Answer	Incorrect and Illogical
Key	5	2	0
No Key But Right Track	4	2	0
Never on Track	1	2	0

The relative grade frequencies observed by scenario were as follows:

Table 3.2

Observed Relative Frequency By Scenario

Information \ Conclusion		Correct Answer % of all subjects	Incorrect But Logical	Incorrect and Illogical
Key	Scenario #1	52.4%	0%	9.5%
	Scenario #2	23.8%	2.4%	4.8%
	Scenario #3	63.6%	0%	3.0%
	Scenario #4	43.2%	2.7%	0%
No Key But Right Track	Scenario #1	4.8%	19.0%	14.3%
	Scenario #2	2.4%	2.4%	4.8%
	Scenario #3	3.0%	9.1%	6.1%
	Scenario #4	2.7%	29.7%	13.5%
Not on Track	Scenario #1	0%	0%	0%
	Scenario #2	0%	4.8%	54.8%
	Scenario #3	0%	0%	15.2%
	Scenario #4	0%	8.1%	0%

From these data it would appear that scenario 3 was the least ambiguous of all. Nearly 65 percent of the subjects taking the mag failure scenario found the key and correctly identified the problem. Scenario 2, the vacuum pump failure appears to be the most difficult. Nearly 55 percent of the subjects taking that scenario drew conclusions which could not be supported by the data they collected. In most cases they seemed to have an ice fixation and blamed their symptoms on a frozen pitot-static system in spite of no collaborating evidence. When faced with a genuine frozen static port scenario they were much more logical with only

13 percent drawing conclusions which could not be supported by data. This may reflect the fact that many of these subjects seemed obsessed with ice problems and blamed ice for any conflicting flight instrument readings.

D. Depiction of Destination Diversion Information Seeking Patterns

Appendix D presents the CRT displays given to the subject for the destination diversion phase of testing. In this scenario the pilot loses his alternator in IMC conditions beyond the range of his destination or departure airports. He must choose between alternate airports with different attributes. Such attributes include ceiling, visibility, bearing and distance, navigation aids, presence of ATC support and terrain. In this test there is no absolute answer; rather, the test seeks to see how pilots weigh information about alternative airports.

The Destination Information Graph (DIG) provides a quick way to summarize the information seeking style of an individual subject. The DIG's portray:

(a) the type of information sought

(b) the frequencies with which information items are queried

(c) the order in which airports are considered

(d) the ultimate choice of which alternate airport is selected and how much data that decision required compared to airports considered but not selected

Figure 3-7 illustrates a typical DIG. This particular subject asked for information on only three airports, although his search was nearly total over the information available for each. The airport selected, number 6, was the first one he searched.

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Subject #67
Time Lapsed: 134
Sec./Port Selection: 13.33
Sec./Inquiry: 5.875
Airport Selected: #6

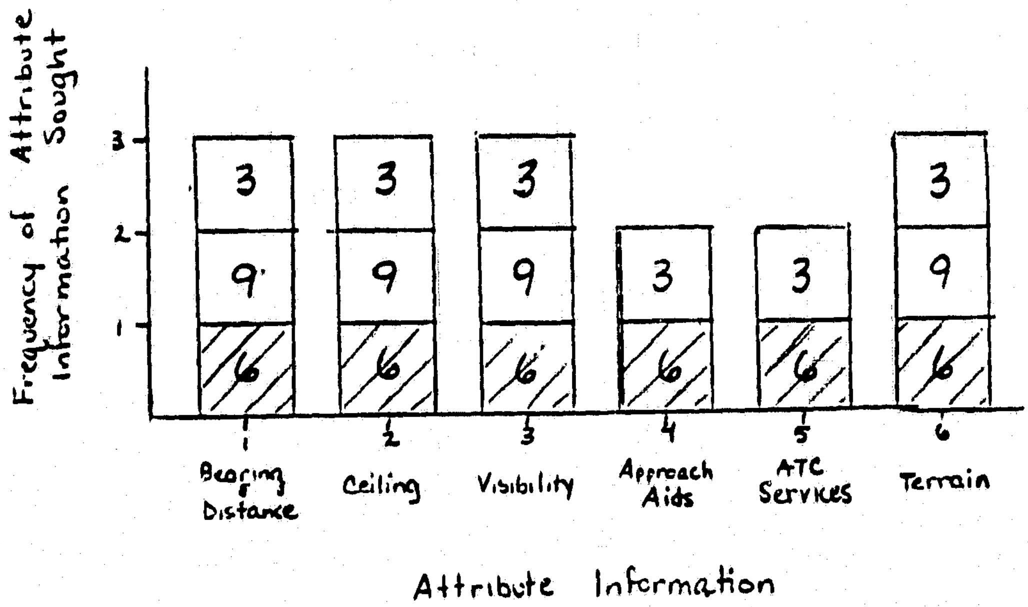

Figure 3-7. Destination-Diversion Quick Decision

E. Subject Background

A total of forty-two subjects participated in the computer aided testing (CAT) program. All were rated pilots ranging from Private to ATP. Four subjects were used for special purpose testing leaving thirty-eight who participated in full sets of CAT experiments. Forty-two percent were private pilots, forty-two percent were commercial pilots and sixteen percent held the ATP rating. Eighty-eight percent of the private pilots were not instrument rated. This group was recruited to investigate whether or not the CAT scenarios could separate performance of pilots with IFR versus VFR experience.

Total flying time among subjects ranged from fifty hours to 15,000 hours, the average being 1,654 hours. Their single-engine experience ranged from fifty to 7,500 with an average of 933 hours. Instrument flying experience, which in the case of non-rated private pilots included elementary hood time, averaged 257 hours. The most experienced instrument pilot reported 1,500 hours of instrument flying experience. Histograms reflecting this broad range of flying experience among subjects are shown in Figures 3-8, 3-9, and 3-10.

Knowledge survey scores ranged from twenty-five to eighty percent with an average of 56.6. Although individual subjects were weaker in some areas than others, the average percent correct by category across all subjects was nearly constant. The distribution of knowledge scores is given by Figure 3-11.

A brief summary of pertinent biographical information for each subject is given in Table 3-3. A complete subject data record,

PERCENTAGE BAR CHART

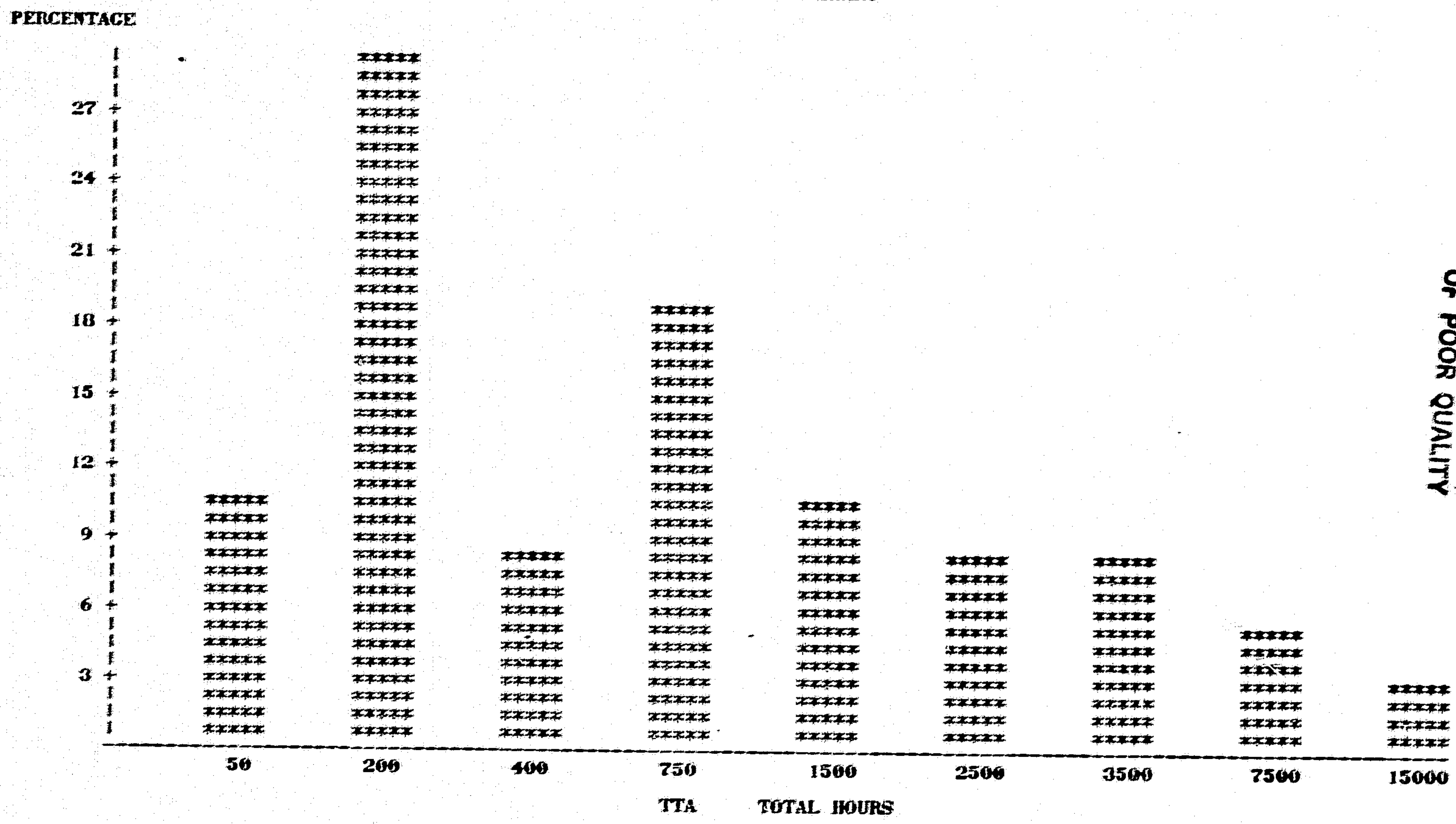

Figure 3-8: Distribution of Total Flying Experience

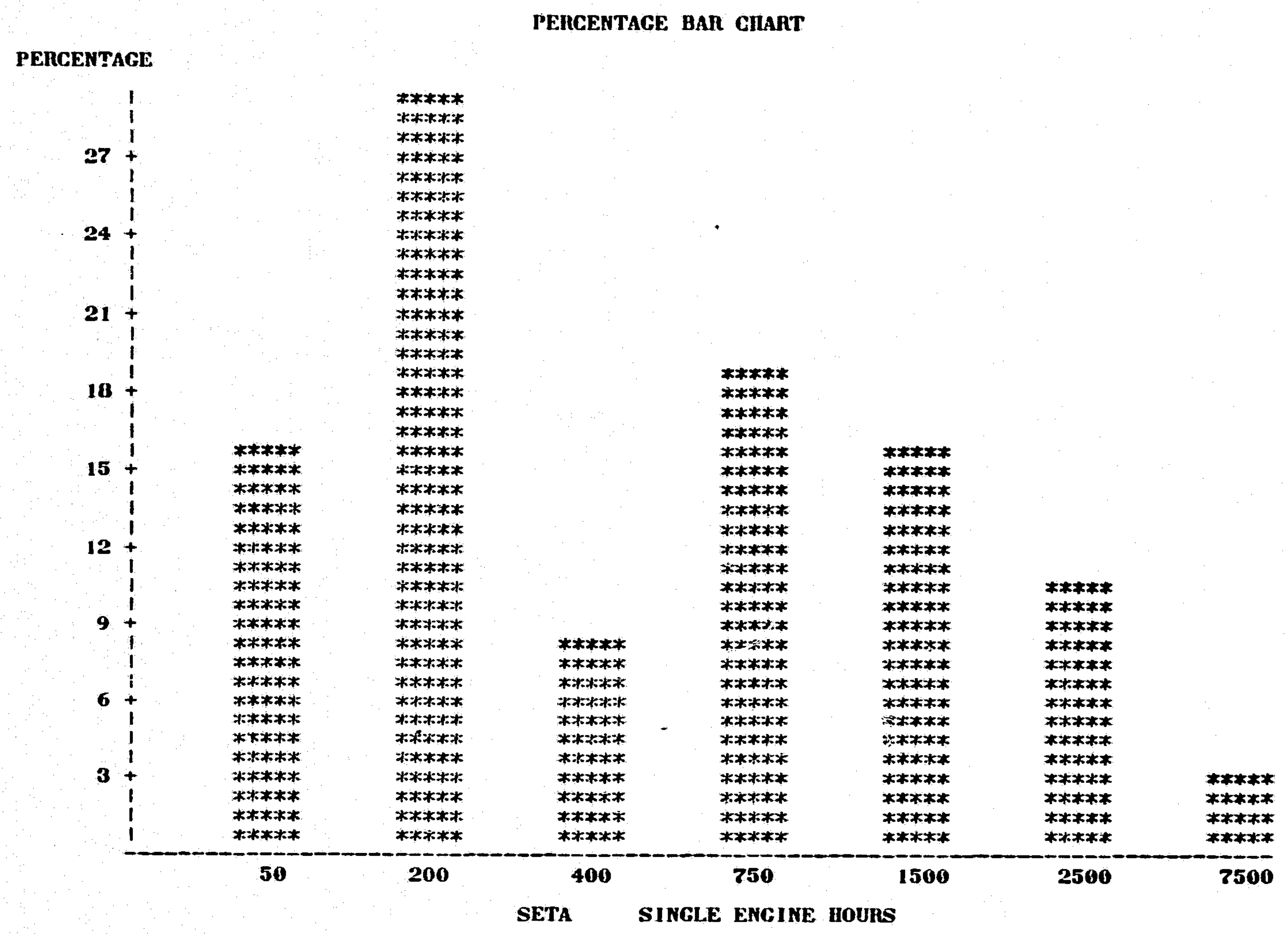

Figure 3-9: Distribution of Single Engine Flying Experience

PERCENTAGE BAR CHART

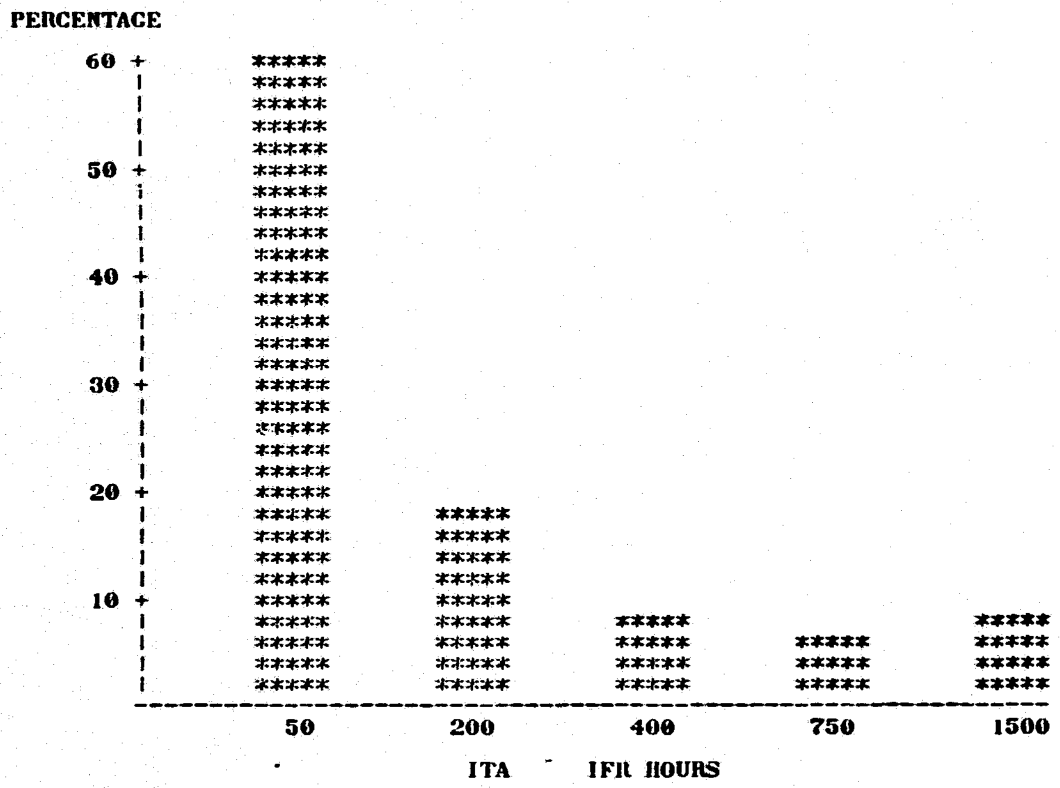

Figure 3-10: Distribution of Instrument Flying Experience

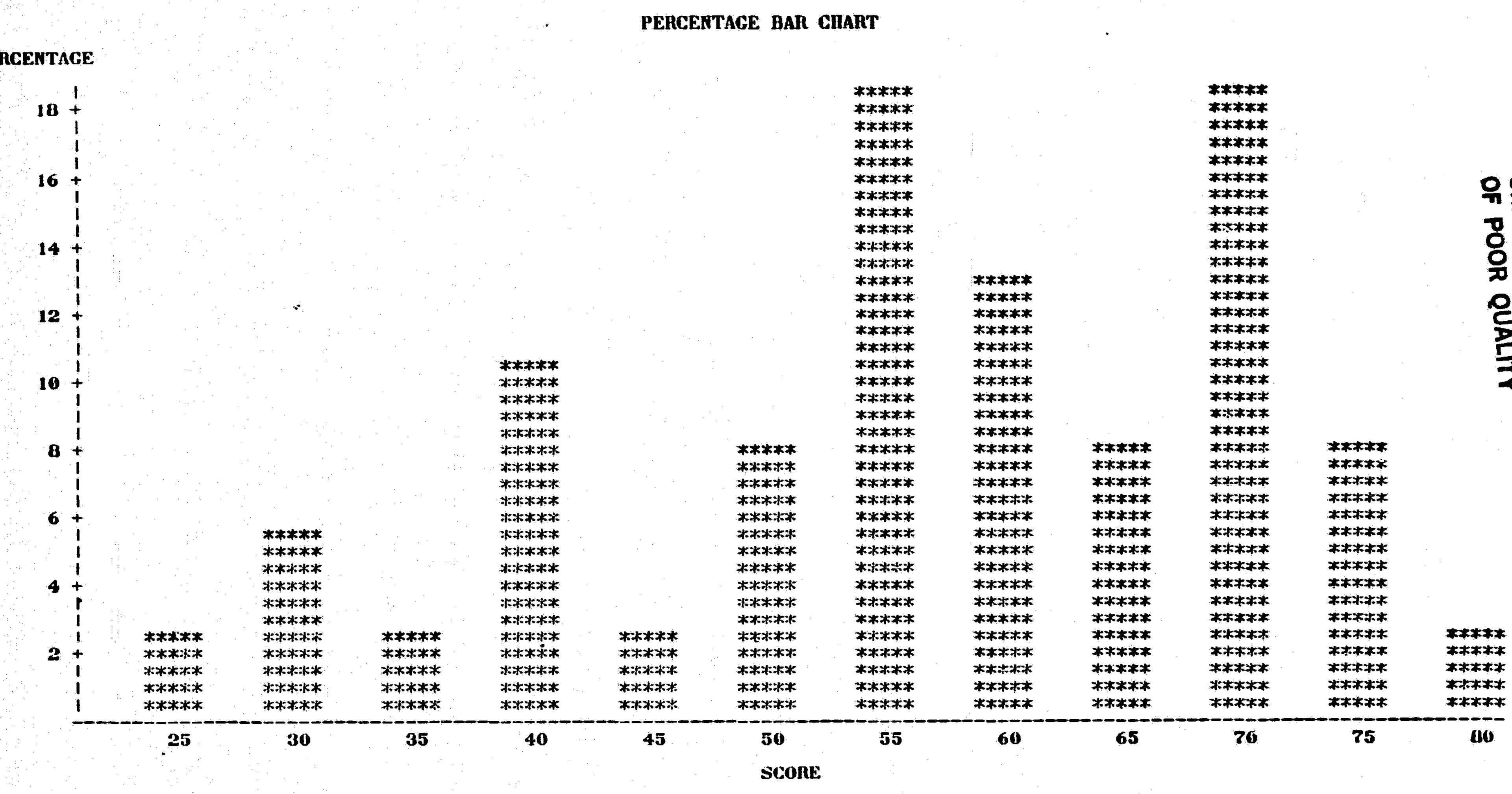

Figure 3-11: Distribution of Knowledge Scores

including response to all scenarios is available in the Master Data Table, Table 3-5. A description of the variables contained in the Master Data Table is available in Table 3-4.

F. Diagnostic Performance

Means and standard deviations for all performance variables are listed in Table 3-6. Correctness scores are portrayed in Figure 3-12. This histogram illustrates an extremely wide spread in performance. Nearly eight percent of the subjects completely missed every scenario for a net score of zero while only three percent were able to achieve a perfect correctness score. The average percent total correct was 47. Individual scenario scores are more enlightening. Out of a maximum of five points for each scenario, the averages are 3.31, 1.46, 3.33, and 3.00 for scenarios one through four respectively. It is obvious that scenario two, the vacuum pump failure, posed significantly more problems in diagnosis than did the others. This is especially noteworthy in view of the current failure rates in general aviation vacuum pumps. These data seem to indicate that pilots may have difficulty in recognizing the symptoms of such failures.

Regression Analysis

In order to investigate what factors predict performance measures, a series of stepwise regressions were performed. These are listed in Table 3-7 and 3-8. Each table indicates the dependent variable, R^2, N, and three sets of independent variables (biographical and experience, knowledge, independent performance variables) from which the predictor variables are chosen. Table 3-7 indicates

the regression models attained for the correctness scores on scenarios one through four. Predictive variables included knowledge survey score, number of inquiries, number of tracks, and the mean delta (decision and response) time. Maximum R-square improvement was chosen. A significance level (α) of 0.1 was chosen. Four subjects' (69-73) time data had to be deleted since they were given unlimited time to complete a protocol analysis. The MAXR stepwise technique employed by SAS will eliminate a subject's data from consideration if that subject has any missing values for the variables included in the regression procedure. This accounts for the removal of seventeen subjects from the first set of regression models shown in Table 3-7.

The general strategy was to include all predictor (independent) variables, even those which could be related to each other, e.g. DIFTT (total tracks - total unique tracks) and total tracks and total unique tracks. However, no variable could be introduced if it had been derived from another significant predictor variable. On the other hand, no predictor variable which formed part of the dependent variable was allowed in the regression. For example, since TOTCORR = C1 + C2 + C3 + C4, a predictor variable for TOTCORR could not be introduced which contained either C1, C2, C3, or C4, e.g., Z_t. (Z_t = total correct/total tracks). The reader is referred to Table 3-4 for complete definitions of symbols and terms.

The strategy employed in deriving the regression models presented in Table 3-8 is slightly different from that described above. The objective here was to condense the candidate predictor

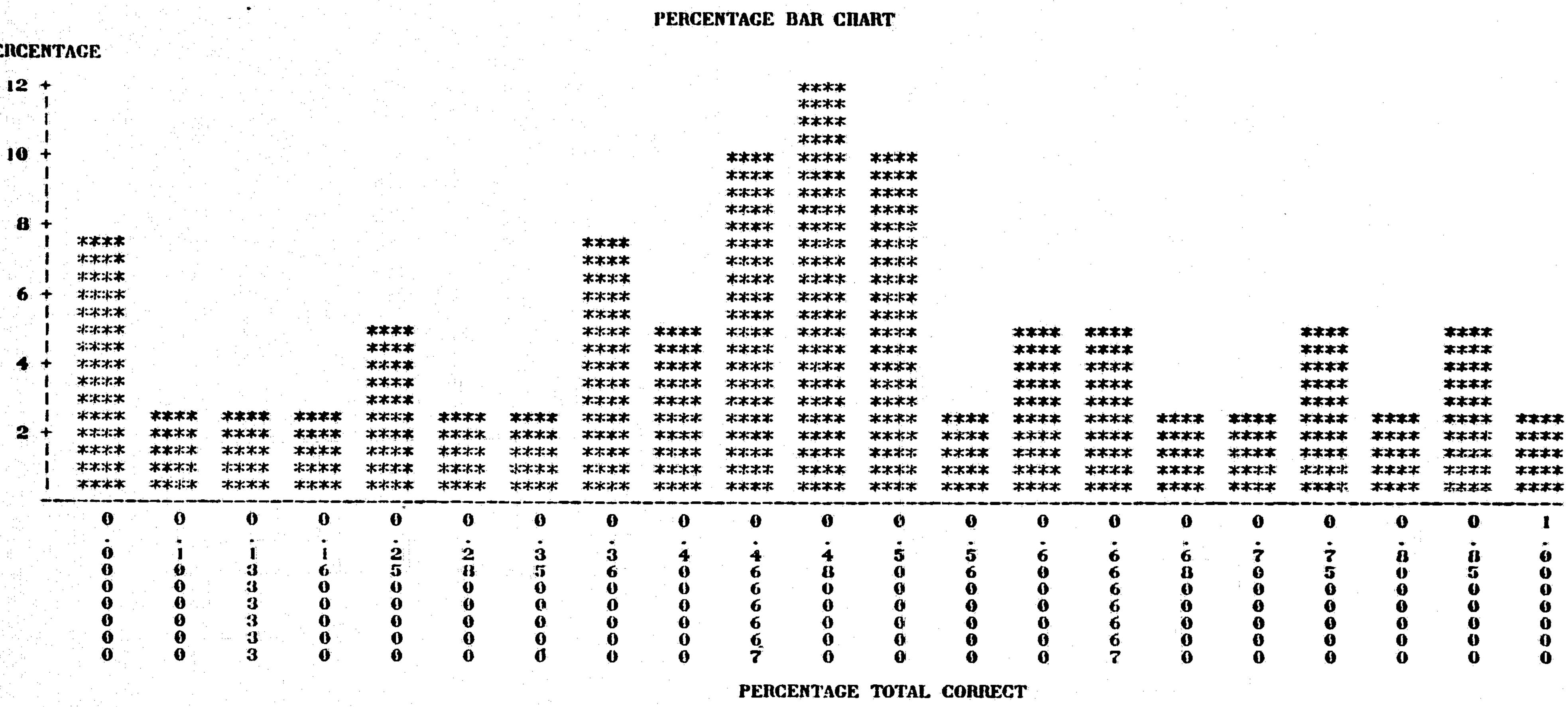

Figure 3-12: Distribution of Diagnostic Scores

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OBS	SUBJECT	AGE	RATING	TRAINING	FLYING BACKGROUND	RECENCY	TOTHRS	SEHRS	IFRHRS	SCORE
1	42	51-60	PRIVATE VFR	CIVILIAN	PLEASURE	30 DAYS	200	200	50	55
2	43	31-40	PRIVATE VFR	CIVILIAN	BUSINESS	30 DAYS	200	50	50	75
3	44	20-30	AIR TRANSPORT	CIVILIAN	COMMERCIAL	30 DAYS	3500	2500	400	60
4	45	20-30	COMMERCIAL IFR	CIVILIAN	COMMERCIAL	30 DAYS	750	750	50	55
5	46	20-30	COMMERCIAL IFR	CIVILIAN	COMMERCIAL	30 DAYS	750	750	50	70
6	47	51-60	AIR TRANSPORT	CIVILIAN	PLEASURE	30 DAYS	1500	1500	200	80
7	48	20-30	AIR TRANSPORT	CIVILIAN	COMMERCIAL	90 DAYS	3500	2500	750	65
8	49	20-30	COMMERCIAL IFR	CIVILIAN	COMMERCIAL	30 DAYS	750	750	50	55
9	50	20-30	COMMERCIAL IFR	CIVILIAN	COMMERCIAL	30 DAYS	400	400	200	70
10	51	20-30	PRIVATE VFR	CIVILIAN	PLEASURE	30 DAYS	50	50	50	40
11	52	20-30	COMMERCIAL IFR	CIVILIAN	COMMERCIAL	30 DAYS	1500	750	50	70
12	53	20-30	PRIVATE VFR	CIVILIAN	PLEASURE	30 DAYS	200	200	50	60
13	54	20-30	COMMERCIAL IFR	MILITARY	MILITARY	30 DAYS	750	50	200	40
14	55	31-40	COMMERCIAL IFR	CIVILIAN	COMMERCIAL	30 DAYS	750	750	50	50
15	56	31-40	COMMERCIAL IFR	MILITARY	PLEASURE	30 DAYS	1500	1500	200	55
16	57	41-50	PRIVATE VFR	CIVILIAN	PLEASURE	30 DAYS	400	400	50	50
17	58	41-50	AIR TRANSPORT	MILITARY	COMMERCIAL	30 DAYS	7500	2500	1500	70
18	59	20-30	COMMERCIAL IFR	CIVILIAN	PLEASURE	30 DAYS	1500	1500	50	55
19	60	20-30	PRIVATE VFR	CIVILIAN	PLEASURE	90 DAYS	200	200	50	25
20	61	20-30	PRIVATE VFR	CIVILIAN	PLEASURE	30 DAYS	200	200	50	65
21	62	51-60	PRIVATE VFR	CIVILIAN	PLEASURE	30 DAYS	200	200	50	65
22	63	<20	PRIVATE VFR	CIVILIAN	PLEASURE	90 DAYS	200	200	50	55
23	64	20-30	PRIVATE VFR	CIVILIAN	PLEASURE	180 DAYS	200	200	200	45
24	65	20-30	PRIVATE VFR	CIVILIAN	PLEASURE	30 DAYS	50	50	50	35
25	66	<20	PRIVATE VFR	CIVILIAN	PLEASURE	30 DAYS	200	200	50	40
26	67	20-30	PRIVATE VFR	CIVILIAN	PLEASURE	30 DAYS	50	50	50	50
27	68	20-30	PRIVATE VFR	CIVILIAN	PLEASURE	30 DAYS	50	50	50	60
28	69	20-30	COMMERCIAL IFR	CIVILIAN	COMMERCIAL	30 DAYS	750	750	50	70
29	70	51-60	COMMERCIAL IFR	MILITARY	BUSINESS	30 DAYS	15000	7500	1500	75
30	71	<20	COMMERCIAL IFR	CIVILIAN	PLEASURE	30 DAYS	400	400	200	55
31	72	20-30	AIR TRANSPORT	CIVILIAN	COMMERCIAL	30 DAYS	2500	2500	400	75
32	73	20-30	COMMERCIAL IFR	CIVILIAN	BUSINESS	30 DAYS	750	750	200	40
33	74	41-50	PRIVATE VFR	CIVILIAN	PLEASURE	30 DAYS	400	400	200	55
34	75	31-40	COMMERCIAL IFR	MILITARY	MILITARY	>2 YEARS	2500	200	750	30
35	78	31-40	COMMERCIAL IFR	MILITARY	PLEASURE	30 DAYS	2500	1500	400	70
36	80	20-30	AIR TRANSPORT	CIVILIAN	COMMERCIAL	30 DAYS	3500	1500	1500	70
37	81	31-40	PRIVATE VFR	CIVILIAN	PLEASURE	30 DAYS	200	200	50	30
38	82	51-60	COMMERCIAL IFR	CIVILIAN	PLEASURE	30 DAYS	7500	1500	50	60
39	83	20-30	PRIVATE VFR	CIVILIAN	PLEASURE	30 DAYS	200	200	50	60

Table 3-3. Subject Biographical Information

*THE FOLLOWING SECTION IS A BRIEF DESCRIPTION OF THE VARIABLES

BIOGRAPHICAL SURVEY

```
STUDENT    : STUDENT IDENTIFICATION NUMBER
CERT       : PILOT CERTIFICATION
              1=STUDENT          PILOT
              2=PRIVATE          PILOT
              3=COMMERCIAL       PILOT
              4=AIR TRANSPORT PILOT
RAT        : AIRMAN RATINGS
              1=REPAIRMAN
              2=AIRCRAFT MECHANIC
              3=POWPLT.  MECHANIC
              4=FLIGHT ENGINEER
              5=INSTRUMENT RATING
              6=CERTIFIED FLIGHT INSTRUCTOR
              7=ASEI
              8=AMEI
              9=ROTARY WING
             10=INSPECTOR AUTHORIZATION
             11=NONE OF THE ABOVE
TT         : TOTAL FLYING EXPERIENCE IN HRS.
              1=< 100
              2=100-300
              3=301-500
              4=501-1000
              5=1001-2000
              6=2001-3000
              7=3001-4000
              8=4001-5000
              9=5001-10000
             10=10001-20000
             11=<20000
SET        : SINGLE ENGINE FLYING EXPERIENCE
              1=< 100
              2=100-300
              3=301-500
              4=501-1000
              5=1001-2000
              6=2001-3000
              7=3001-4000
              8=4001-5000
              9=5001-10000
             10=10001-20000
             11=<20000
IT         : INSTRUMENT    FLYING EXPERIENCE
              1=< 100
              2=100-300
              3=301-500
              4=501-1000
              5=1001-2000
              6=2001-3000
              7=3001-4000
              8=4001-5000
              9=5001-10000
```

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Table 3-4: Description of Variables

```
          10=10001-20000
          11=<20000
BI      : BIANNUAL FLIGHT TEST
           1= LAST 30  DAYS
           2= LAST 90  DAYS
           3= LAST 180 DAYS
           4= LAST 360 DAYS
           5= LAST 2   YRS.
           6= OVER 2   YRS.
PIC     :  PILOT IN COMMAND HRS.
           1= LAST 30  DAYS
           2= LAST 90  DAYS
           3= LAST 180 DAYS
           4= LAST 360 DAYS
           5= LAST 2   YRS.
           6= OVER 2   YRS.
IFR     :  INSTRUMENT FLIGHT RULES, PLAN SUBMITTED
           1= LAST 30  DAYS
           2= LAST 90  DAYS
           3= LAST 180 DAYS
           4= LAST 360 DAYS
           5= LAST 2   YRS.
           6= OVER 2   YRS.
INST    :  LAST FLEW ON IFR
           1= LAST 30  DAYS
           2= LAST 90  DAYS
           3= LAST 180 DAYS
           4= LAST 360 DAYS
           5= LAST 2   YRS.
           6= OVER 2   YRS.
SO      :  SOURCE OF INSTRUMENT FLIGHT TRAINING
            1=MILITARY
            2=CIVIL-FORMAL
            3=CIVIL-FREELANCE
CUR     : CURRENT FLYING ACTIVITIES  INCICATOR VARIABLES  1=YES 0=NO
           1=AIRLINE  FLIGHT CREW
          2=MILITARY FLIGHT CREW
           3=CA(HIRED PILOT)
          4=CA(PERSONAL BUSINESS)
          5=CA(PERSONAL PLEASURE)
PRI     : PRIMARY FLYING ACTIVITIES  INDICATOR VARIABLES  1=YES 0=NO
           1=AIRLINE  FLIGHT CREW
          2=MILITARY FLIGHT CREW
          3=CA(HIRED PILOT)
          4=CA(PERSONAL BUSINESS)
          5=CA(PERSONAL PLEASURE)
ACE     : 1=UNDER 20
          2=20-30
          3=31-40
          4=41-50
          5=51-60
          6=61-70
          7=OVER 70
HIST    : WHEN PILOT WAS 1ST. RATED OR WHEN CERTIFICATION WAS RECEIVED
          1=BEFORE 1940
          2=1940-45
```

Table 3-4: (continued)

```
        3=1946-50
        4=1951-55
        5=1956-60
        6=1961-65
        7=1966-70
        8=1971-75
        9=1976-1980
       10=AFTER 1980

                  KNOWLEDGE SURVEY

SCORE      : PERCENTAGE SCORE ON KNOWLEDGE SURVEY
CATSCR     : CATEGORY  SCORE ON KNOWLEDGE SURVEY
              1=KNOWLEDGE SUBSCORE FOR ENGINE AND FUEL SYSTEMS
              2=KNOWLEDGE SUBSCORE FOR ELECTRICAL SYSTEMS AND COCKPIT INST.
              3=KNOWLEDGE SUBSCORE FOR WEATHER AND IFR OPERATIONS

              DESTINATION DIVERSION TEST

ORDER      : ORDER THAT SUBJECT REQUESTED INFORMATION IN
PORT       : AIRPORT DESIGNATION NUMBER
INFO       : TYPE OF INFORMATION REQUESTED
              1=BEARING AND DISTANCE
              2=CEILING
              3=VISIBILITY
              4=APPROACH AIDS
              5=ATC SERVICES AVAILABLE
              6=TERRAIN
CTIM       : CUMULATIVE TIME
OLDCTIM    : PREVIOUS CTIM
DELTA      : CTIM-OLDCTIM
SELEC      : AIRPORT SELECTED IN DEST. DIV. TEST
YN         : YES/NO VARIABLE
              1=YES MEANING PILOT WOULD     ATTEMPT THIS FLIGHT
              2=NO  MEANING PILOT WOULD NOT ATTEMPT THIS FLIGHT
MEANDT     : MEAN OF THE DELTA TIMES FOR INQUIRIES
VARDT      : VARIANCE OF THE DELTA TIMES FOR INQUIRIES
MEANPA     : MEAN OF THE TIMES TO PICK AN AIRPORT
VARPA      : VARIANCE OF THE TIMES TO PICK AN AIRPORT
TOTINQDD   : TOTAL NUMBER OF INQUIRIES IN DESTINATION DIVERSION
TOTAIRP    : TOTAL NUMBER OF AIRPORTS PICKED
UNIQAIRP   : NUMBER OF UNIQUE AIRPORTS LOOKED AT
MINQAIR    : MEAN NUMBER OF INQUIRIES PER AIRPORT
VINQAIR    : VARIANCE OF THE NUMBER OF INQUIRIES PER AIRPORT

                  SCENARIOS

INQUIRIES  : NUMBER OF INQUIRIES  IN SCENARIO #N
CTIM       : CUMULATIVE TIME
OLDCTIM    : PREVIOUS CTIM
DELTA      : CTIM-OLDCTIM
 FTLB1-FTLB4: FLYING TIME LEFT BEFORE DIAGNOSIS GIVEN IN SCEN 1-4
               1= 0-5 MINUTES
               2= 5-30 MINUTES
               3= AS LONG AS FUEL PERMITS
 CRITB 1-4 : CRITICALITY OF PROBLEM BEFORE DIAGNOSIS GIVEN IN
```

Table 3-4: (continued)

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		SCENARIOS 1-4 VALUED:FROM 1-7
CRITA 1-4	:	CRITICALITY OF PROBLEM AFTER DIAGNOSIS GIVEN IN SCENARIOS 1-4 VALUED:FROM 1-7
CONF 1-4	:	CONFIDENCE OF OWN DIAGNOSIS BEFORE DIAGNOSIS GIVEN IN SCENARIOS 1-4 VALUED:FROM 1-10
FTLA 1-4	:	FLYING TIME LEFT AFTER DIAGNOSIS GIVEN IN SCENARIOS 1-4 1= 0-5 MINUTES 2= 5-30 MINUTES 3= AS LONG AS FUEL PERMITS
C1-C5	:	CORRECTNESS SCORES ON SCENARIOS 1-5
TOTCOR	:	C1+C2+C3+C4
MEAN 1-5	:	MEAN OF THE DELTA TIMES FROM SCENARIOS 1-5
VAR 1-5	:	VARIANCE OF THE DELTA TIMES FROM SCENARIOS 1-5
TOTRAK	:	TOTAL NUMBER OF TRACKS
UNIQTRAK	:	TOTAL NUMBER OF UNIQUE TRACKS
TOCT	:	TOTAL NUMBER OF TIMES ON THE CORRECT TRACK
CORINQ	:	TOTAL NUMBER OF INQUIRIES ON THE CORRECT TRACK
TOTINQ	:	TOTAL NUMBER OF INQUIRIES FOR ALL FOUR SCENARIOS
SETA	:	MIDPOINTS OF THE RANGES FOR SINGLE ENGINE HOURS
TTA	:	MIDPOINTS OF THE RANGES FOR TOTAL FLYING EXPERIENCE
ITA	:	MIDPOINTS OF THE RANGES FOR INSTRUMENT FLYING EXPERIENCE
SETLOG	:	NATURAL LOGORITHM OF SINGLE ENGINE FLYING HOURS
TTLOG	:	NATURAL LOGORITHM OF TOTAL FLYING HOURS
INPTRT	:	RATIO OF TOTAL INQUIRIES TO TOTAL TRACKS FOR ALL FOUR SCENARIOS
ZT	:	RATIO OF TOTAL CORRECT TO TOTAL NUMBER OF TRACKS FOR ALL FOUR SCENS.
DIFTT	:	DIFFERENCE BETWEEN NUMBER OF TOTAL TRACKS AND NUMBER OF UNIQUE TRACK
MDELTAT	:	THE MEAN DELTA TIME ON ALL 4 SCENARIOS FOR EACH SUBJECT
SCEN	:	NUMBER OF SCENARIOS COMPLETED BY EACH SUBJECT
KEY	:	YES/NO RESPONSE CORRESPONDING TO WHETHER THE SUBJECT HIT UPON THE CORRECT ITEM DURING DIAGNOSTIC SEARCH;

Table 3-4: (continued)

STUDENT	STUDENT	CERT	RAT1	RAT2	RAT3	RAT4	RAT5	RAT6	RAT7	RAT8	RAT9	RAT10	TET	SET	IT	TTA	SETA	ITA	SO	BI	PIC	IFR	INST	ACE	HIST	CUR1	CUR2	CUR3	CUR4	CUR5	PRI1	PRI2	PRI3	PRI4	PRI5	SCORE	CATSCR1	CATSCR2	CATSCR3	FTLB1	CRITB1	CONF1	FTLA1	CRITA1	C1
42	42	2	0	0	0	0	1	0	1	0	0	0	2	2	1	200	200	50	3	5	1	1	2	5	8	0	0	0	1	1	0	0	0	1	1	55	4	3	4	.	.	.	.	.	5
43	43	2	0	0	0	0	1	0	1	0	0	0	2	1	1	200	50	50	2	5	1	1	1	3	9	0	0	0	1	1	0	0	0	1	0	75	7	3	5	3	4	9	3	3	4
44	44	4	0	0	0	0	1	1	1	1	0	0	7	6	3	3500	2500	400	2	4	1	1	2	2	8	0	0	1	0	1	0	0	1	0	0	60	5	3	4	1	7	9	3	2	2
45	45	3	0	0	0	0	1	1	1	1	0	0	4	4	1	750	750	50	2	4	1	1	1	2	8	0	0	1	0	0	0	0	1	0	0	55	6	3	2	3	5	5	3	5	0
46	46	3	0	0	0	0	1	1	1	1	0	0	4	4	1	750	750	50	2	4	1	1	1	2	9	0	0	1	0	1	0	0	1	0	0	70	5	5	4	2	6	8	3	2	5
47	47	4	0	1	0	0	0	1	0	1	0	0	5	5	2	1500	1500	200	2	5	1	1	1	5	6	0	0	0	1	1	0	0	0	1	1	80	5	5	6	2	7	10	2	7	5
48	48	4	0	0	0	0	1	1	1	1	0	0	7	6	4	3500	2500	750	2	2	2	2	2	2	8	1	0	1	1	0	0	0	1	0	0	65	4	4	5	2	5	7	3	4	0
49	49	3	0	0	0	0	0	1	1	1	0	0	4	4	1	750	750	50	2	5	1	4	4	2	9	0	0	1	0	1	0	0	1	0	0	55	4	2	5	3	4	7	3	3	0
50	50	3	0	0	0	0	1	1	1	1	0	0	3	3	2	400	400	200	2	4	1	1	1	2	9	0	0	1	0	0	0	0	1	0	0	70	5	5	4	2	6	8	3	4	0

STUDENT	TOTINQ1	MAXDT1	TOTRAK1	UNTRAK1	TROCT1	CORINQ1	KEY1	FTLB2	CRITB2	CONF2	FTLA2	CRITA2	C2	TOTINQ2	MAXDT2	TOTRAK2	UNTRAK2	TROCT2	CORINQ2	KEY2	FTLB3	CRITB3	CONF3	FTLA3	CRITA3	C3	TOTINQ3	MAXDT3	TOTRAK3	UNTRAK3	TROCT3	CORINQ3	KEY3	FTLB4	CRITB4	CONF4	FTLA4	CRITA4	C4	TOTINQ4	MAXDT4	TOTRAK4	UNTRAK4	TOCT4
42	9	60	5	4	2	3	Y	.	.	.	.	.	0	13	52	5	4	1	3	N	.	.	.	.	.	5	17	47	7	4	2	4	Y	.	.	.	.	.	5	13	38	6	5	2
43	3	29	1	1	1	3	N	1	6	1	3	3	2	19	65	7	5	2	2	N	3	4	10	3	4	5	16	22	8	4	2	6	Y	3	3	8	3	2	5	10	25	4	3	2
44	10	18	5	4	0	0	N	3	6	8	3	6	0	21	76	8	5	1	1	N	.	.	.	.	.	.	0	0	.	.	.	.		3	3	9	3	5	5	32	27	12	5	3
45	20	40	4	3	1	5	Y	3	6	9	3	6	5	15	48	9	3	3	5	Y	2	6	7	3	5	0	20	25	8	4	0	0	N	3	2	2	3	5	0	27	31	9	4	4
46	6	29	3	3	1	1	Y	3	1	9	3	2	0	7	62	2	2	0	0	N	3	5	8	3	5	5	15	33	4	4	1	4	Y	3	5	7	3	5	5	32	25	11	5	4
47	6	19	1	1	1	5	Y	3	3	10	3	4	2	12	53	5	3	0	0	N	3	5	5	3	6	0	23	33	7	5	1	6	Y	3	5	8	3	4	0	17	80	4	3	2
48	9	24	2	2	1	1	N	1	7	5	3	3	0	13	49	3	3	1	1	N	3	5	5	3	6	0	28	32	2	2	0	0	N	3	5	8	3	5	5	15	38	6	3	2
49	5	8	1	1	1	5	Y	3	5	10	3	5	5	3	9	1	1	1	3	Y	3	5	10	3	4	5	7	23	3	3	1	3	Y	3	4	10	3	2	0	5	59	2	2	1
50	9	41	5	3	3	3	N	3	5	6	3	5	4	27	18	9	4	4	6	N	3	3	10	3	3	5	41	19	17	7	1	4	Y	3	2	10	3	2	5	8	12	4	2	2

Table 3-5. Master Data Table

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STUDENT	CORINQ4	KEY4	INPTR1	DIFT1	INPTR2	DIFT2	INPTR3	DIFT3	INPTR4	DIFT4	MEAN1	VAR1	MEAN2	VAR2	MEAN3	VAR3	MEAN4
42	7	Y	1.80000	1	2.60000	1	2.4286	3	2.16667	1	16.4444	337.778	18.0000	241.00	13.7059	213.721	13.7692
43	7	Y	3.00000	0	2.71429	2	2.0000	4	2.50000	1	22.0000	93.000	12.2632	224.76	6.6250	29.[illegible]	6.0000
44	12	Y	2.00000	1	2.62500	3	.	.	2.66667	7	6.4000	34.489	10.6190	270.65	.	.	4.4375
45	8	N	5.00000	1	1.66667	6	2.5000	4	3.00000	5	8.5500	108.155	9.0000	153.43	7.5000	49.211	5.7778
46	9	Y	2.00000	0	3.50000	0	3.7500	0	2.90909	6	19.0000	83.600	17.2857	462.57	9.5333	90.410	6.7813
47	3	N	6.00000	0	2.40000	2	3.2857	2	4.25000	1	9.6667	30.267	18.9167	313.17	8.0000	55.455	13.2941
48	8	Y	4.50000	0	4.33333	0	14.0000	0	2.50000	3	10.2222	50.694	11.2308	156.03	6.8571	54.942	7.6000
49	3	N	5.00000	0	3.00000	0	2.3333	0	2.50000	0	4.8000	6.700	5.3333	12.33	7.1429	55.810	13.8000
50	6	Y	1.80000	2	3.00000	5	2.4118	10	2.00000	2	26.4444	121.028	5.5926	22.10	3.7073	16.712	3.8750

STUDENT	VAR4	MEAN5	VAR5	SCEN	MDELTAT	TOTRAK	UNIQTRAK	TOCT	CORINQ	TOTINQ	ZT	AVCTOTRK	AVCUNIQT	AVCTOCT	AVCCORIN	AVCTOTIN	AVCZT	INPTRT
42	141.526	.	.	4	15.4799	23	17	7	17	52	0.65217	5.75	4.25	1.75	4.25	13.00	0.163043	2.26087
43	56.222	.	.	4	11.7220	20	13	7	18	48	0.80000	5.00	3.25	1.75	4.50	12.00	0.200000	2.40000
44	25.931	.	.	3	7.1522	.	.	.	.	63	.	.	.	.	.	21.00	.	.
45	42.949	.	.	4	7.7069	30	14	8	18	82	0.16667	7.50	3.50	2.00	4.50	20.50	0.041667	2.73333
46	62.628	.	.	4	13.1501	20	14	6	14	60	0.75000	5.00	3.50	1.50	3.50	15.00	0.187500	3.00000
47	495.596	.	.	4	12.469[illegible]	17	12	4	14	58	0.41176	4.25	3.00	1.00	3.50	14.50	0.102941	3.41176
48	107.829	.	.	4	8.9775	13	10	4	10	65	0.38462	3.25	2.50	1.00	2.50	16.25	0.096154	5.00000
49	638.700	.	.	4	7.7690	7	7	4	14	20	1.42857	1.75	1.75	1.00	3.50	5.00	0.357143	2.85714
50	15.554	.	.	4	9.9048	35	16	10	19	85	0.40000	8.75	4.00	2.50	4.75	21.25	0.100000	2.42857

Table 3-5. Master Data Table (continued)

STUDENT	AVGINPTR	DIFTT	AVGDIFTT	TOTCOR	PTOTCOR	SETLOC	TTLOC	TCRITBEF	TCRITAF	MEANDT	VARDT	MEANPA	VARPA	TOTINQDD	TOTAIRP	UNIQAIRP	MINQAIR	VINQAIR	YN	SELEC
42	0.56522	6	1.50	15	0.75000	5.29832	5.29832	.	.	.	.	.	.	.	.	.	.	.	.	.
43	0.60000	7	1.75	16	0.80000	3.91202	5.29832	17	12	4.500	16.530	26.500	109.900	16	6	4	2.67	1.47	.	16
44	.	.	.	7	0.46667	7.82405	8.16052	.	.	2.833	2.147	12.333	16.333	18	3	3	6.00	0.00	1	14
45	0.68333	16	4.00	5	0.25000	6.62007	6.62007	19	21	2.770	3.314	9.330	6.670	31	6	5	6.20	0.20	.	1
46	0.75000	6	1.50	15	0.75000	6.62007	6.62007	17	14	2.220	1.550	7.670	13.240	44	15	13	2.93	2.07	.	0
47	0.85294	5	1.25	7	0.35000	7.31322	7.31322	20	21	.	.	.	.	.	.	.	.	.	.	.
48	1.25000	3	0.75	5	0.25000	7.82405	8.16052	22	18	.	.	.	.	.	.	.	.	.	.	.
49	0.71429	0	0.00	10	0.50000	6.62007	6.62007	15	14	.	.	.	.	.	.	.	.	.	.	.
50	0.60714	19	4.75	14	0.70000	5.99146	5.99146	16	14	2.250	3.230	13.140	25.740	28	7	6	4.00	0.33	1	7

Table 3-5. Master Data Table (continued)

STUDENT	STUDENT	CERT	RAT1	RAT2	RAT3	RAT4	RAT5	RAT6	RAT7	RAT8	RAT9	RAT10	TT	SET	IT	TTA	SETA	ITA	SO	BI	PIC	IFR	INST	ACE
51	51	2	0	0	0	0	0	0	1	0	0	0	1	1	1	50	50	50	2	4	1	6	4	2
52	52	3	0	0	0	0	1	1	1	1	0	0	5	4	1	500	750	50	2	1	1	1	1	2
53	53	2	0	0	0	0	0	0	1	0	0	0	2	2	1	200	200	50	2	2	1	1	1	2
54	54	3	0	0	0	0	1	0	0	0	0	0	4	1	2	750	50	200	1	1	1	1	1	2
55	55	3	0	0	0	0	1	1	1	0	0	0	4	4	1	750	750	50	2	4	1	6	6	3
56	56	3	0	0	0	0	1	0	1	1	0	0	5	5	2	1500	1500	200	1	4	1	1	1	3
57	57	2	0	0	0	0	0	0	1	0	0	0	3	3	1	400	400	50	3	5	1	6	3	4
58	58	4	0	0	0	0	1	1	1	1	1	0	9	6	5	7500	2500	1500	1	3	1	1	1	4
59	59	3	0	0	0	0	1	1	1	1	0	0	5	5	1	1500	1500	50	2	5	1	4	1	2

STUDENT	HIST	CUR1	CUR2	CUR3	CUR4	CUR5	PRI1	PRI2	PRI3	PRI4	PRI5	SCORE	CATSCR1	CATSCR2	CATSCR3	FTLB1	CRITB1	CONF1	FTLA1	CRITA1	C1
51	9	0	0	0	0	1	0	0	0	0	1	40	2	2	4	2	5	3	3	2	5
52	8	0	0	1	0	0	0	0	1	0	0	70	5	5	4	1	7	10	3	4	5
53	10	0	0	0	0	1	0	0	0	0	1	60	4	5	3	1	7	10	3	3	5
54	9	0	1	0	0	0	0	1	0	0	0	40	3	4	1	1	2	8	3	4	5
55	6	0	0	1	0	0	0	0	1	0	0	50	4	3	3	1	7	10	3	3	5
56	6	0	0	0	1	1	0	0	0	0	1	55	4	5	2	2	4	10	2	4	5
57	7	0	0	0	0	1	0	0	0	0	1	50	5	2	3	1	7	9	3	3	5
58	5	0	0	1	1	1	0	0	1	0	0	70	4	4	6	2	7	10	3	4	0
59	9	0	0	1	0	1	0	0	0	0	1	55	2	3	6	2	5	7	3	2	5

STUDENT	TOTINQ1	MAXDT1	TOTRAK1	UNTRAK1	TROCT1	CORINQ1	KEY1	FTLB2	CRITB2	CONF2	FTLA2	CRITA2	C2	TOTINQ2	MAXDT2	TOTRAK2	UNTRAK2	TROCT2	CORINQ2	KEY2	FTLB3	CRITB3
51	10	63	5	3	2	6	Y	3	3	2	3	5	5	25	48	5	3	1	1	Y	2	6
52	4	15	1	1	1	4	Y	3	3	4	3	4	0	10	24	3	3	0	0	N	3	4
53	10	27	5	3	3	7	Y	3	5	7	3	4	2	9	23	4	3	1	1	Y	2	6
54	9	15	5	3	3	5	Y	1	6	6	3	6	0	16	30	6	4	0	0	N	3	5
55	9	64	4	3	2	7	Y	3	3	6	3	6	0	19	22	6	4	2	2	Y	2	4
56	7	19	3	3	1	1	Y	3	6	5	2	6	0	15	94	4	3	0	0	N	3	6
57	13	31	5	4	2	0	Y	3	4	5	3	3	5	25	59	14	5	3	2	Y	1	7
58	8	15	2	2	0	0	N	3	4	8	3	4	0	7	118	4	4	1	1	N	3	6
59	14	11	4	4	1	2	Y	2	3	5	2	3	0	6	72	4	3	0	0	N	2	2

STUDENT	CONF3	FTLA3	CRITA3	C3	TOTINQ3	MAXDT3	TOTRAK3	UNTRAK3	TROCT3	CORINQ3	KEY3	FTLB4	CRITB4	CONF4	FTLA4	CRITA4	C4	TOTINQ4	MAXDT4	TOTRAK4	UNTRAK4	TROCT4
51	5	3	4.	5	23	19	8	6	1	4	Y	3	5	6	3	5	5	17	15	5	3	2
52	10	3	4	5	14	23	5	4	1	7	Y	2	5	10	3	3	2	7	18	1	1	0
53	9	2	4	5	24	19	10	6	2	5	Y	3	2	8	3	3	5	15	48	7	4	3
54	10	3	5	5	22	15	8	5	1	7	Y	1	6	6	3	5	0	28	21	9	5	1
55	3	3	3	0	9	25	3	2	0	0	N	3	4	9	3	5	5	32	34	17	4	5
56	10	3	5	5	10	7	3	2	1	7	Y	3	4	10	3	6	2	14	34	5	4	1
57	6	3	2	0	36	36	15	6	0	0	N	2	6	7	3	2	2	40	25	18	5	5
58	10	3	6	5	9	17	3	3	1	4	Y	2	6	8	2	5	4	17	34	3	3	1
59	9	2	2	5	10	63	4	3	1	3	Y	2	5	10	2	4	2	13	19	7	4	2

Table 3-5. Master Data Table (continued)

ORIGINAL PAGE IS
OF POOR QUALITY

STUDENT	CORINQ4	KEY4	INPTR1	DIFT1	INPTR2	DIFT2	INPTR3	DIFT3	INPTR4	DIFT4	MEAN1	VAR1	MEAN2	VAR2	MEAN3	VAR3	MEAN4
51	7	Y	2.00000	2	5.00000	2	2.87500	2	3.40000	2	15.3000	396.456	7.4000	127.33	6.3913	42.613	4.4706
52	0	N	4.00000	0	3.33333	0	2.80000	1	7.00000	0	6.2500	35.583	8.5000	63.61	6.7143	45.451	5.0000
53	7	Y	2.00000	2	2.25000	1	2.40000	4	2.14286	3	10.6000	63.378	7.7778	50.94	6.5000	36.522	8.6000
54	4	N	1.80000	2	2.66667	2	2.75000	3	3.11111	4	7.7778	84.944	6.8125	59.36	5.8636	16.123	4.2857
55	9	Y	2.25000	1	3.16667	2	3.00000	1	1.88235	13	13.4444	403.778	5.8421	26.58	17.0000	421.250	5.3433
56	3	N	2.33333	0	3.25000	1	3.33333	1	2.80000	1	12.1429	26.810	18.0769	626.58	4.3000	2.456	7.9286
57	6	N	2.60000	1	1.78571	9	2.40000	9	2.22222	13	9.0000	90.333	9.5600	146.92	6.2778	55.349	5.9250
58	3	N	4.00000	0	1.75000	0	3.00000	0	5.66667	0	7.5000	34.286	28.0000	1638.00	9.6667	24.500	10.7059
59	3	N	3.50000	0	1.50000	1	2.50000	1	1.85714	3	5.2857	14.835	28.3333	696.67	15.6000	394.933	7.2308

STUDENT	VAR4	MEAN5	VAR5	SCEN	MDELTAT	TOTRAK	UNIQTRAK	TOCT	CORINQ	TOTINQ	ZT	AVCTOTRK	AVCUNIQT	AVCTOCT	AVCCORIN	AVCTOTIN	AVCZT	INPTRT
51	15.640	.	.	4	8.3905	23	15	6	18	75	0.86957	5.75	3.75	1.50	4.50	18.75	0.217391	3.[illegible]087
52	35.333	.	.	4	6.6161	10	9	2	11	35	1.20000	2.50	2.25	0.50	2.75	8.75	0.300000	[illegible]000
53	164.400	.	.	4	8.3694	26	16	9	20	58	0.65385	6.50	4.00	2.25	5.00	14.50	0.163462	2.23077
54	19.693	.	.	4	6.1849	28	17	5	16	75	0.35714	7.00	4.25	1.25	4.00	18.75	0.089286	2.67857
55	82.233	.	.	4	10.4076	30	13	9	18	69	0.33333	7.50	3.25	2.25	4.50	17.25	0.083333	2.30000
36	75.456	12.8235	129.15	5	10.6121	15	12	3	11	44	0.80000	3.00	2.40	0.60	2.20	8.80	0.160000	2.93333
57	28.738	8.0909	158.02	5	7.6907	52	20	10	8	114	0.23077	10.40	4.00	2.00	1.60	22.80	0.046154	2.19231
58	136.471	13.0000	249.13	5	13.9681	12	12	3	8	41	0.75000	2.40	2.40	0.60	1.60	8.20	0.150000	3.41667
59	28.859	7.6774	142.96	5	14.1125	19	14	4	8	43	0.63158	3.80	2.80	0.80	1.60	8.60	0.126316	2.26316

Table 3-5. Master Data Table (continued)

ORIGINAL PAGE IS
OF POOR QUALITY

STUDENT	AVGINPTR	DIFTT	AVGDIFTT	TOTCOR	PTOTCOR	SETLOG	TTLOG	TCRITBEF	TCRITAF	MEANDT	VARDT	MEANPA	VARPA	TOTINQDD	TOTAIRP	UNIQAIRP	MINQAIR	VINQAIR	YN	SELEC
51	0.815217	8	2.00	20	1.00	3.91202	3.91202	19	16	2.780	1.310	10.625	12.910	36	8	6	4.50	7.71	1	3
52	0.875000	1	0.25	12	0.60	6.62007	7.31322	19	15	2.390	1.370	8.660	14.500	17	9	6	1.89	0.86	1	14
53	0.557692	10	2.50	17	0.85	5.29832	5.29832	20	14	3.890	13.990	20.700	223.240	19	7	5	2.71	2.57	1	3
54	0.669643	11	2.75	10	0.50	3.91202	6.62007	19	20	3.250	3.857	9.625	38.550	16	8	7	2.00	3.14	0	3
55	0.575000	17	4.25	10	0.50	6.62007	6.62007	18	17	2.150	1.520	17.167	5.340	27	6	5	4.50	6.30	1	3
56	0.586667	3	0.60	12	0.48	7.31322	7.31322	20	21	3.000	4.235	17.250	114.250	18	4	4	4.50	1.00	1	1
57	0.438462	32	6.40	12	0.48	5.99146	5.99146	24	10	4.333	10.030	20.500	39.000	21	4	4	5.25	2.25	1	3
58	0.683333	0	0.00	9	0.36	7.82405	8.92266	23	19	2.560	1.862	19.750	44.250	16	4	4	4.00	0.00	1	1
59	0.452632	5	1.00	12	0.48	7.31322	7.31322	15	11	2.330	1.370	15.670	170.750	36	9	8	4.00	3.25	1	1

Table 3-5. Master Data Table (continued)

ORIGINAL PAGE IS
OF POOR QUALITY

STUDENT	STUDENT	CERT	RAT1	RAT2	RAT3	RAT4	RAT5	RAT6	RAT7	RAT8	RAT9	RAT10	TT	SET	IT	TTA	SETA	ITA	SO	BI	PIC	IFR	INST	ACE	HIST	CUR1	CUR2	CUR3	CUR4	CUR5	PRI1	PRI2	PRI3	PRI4	PRI5	SCORE	CATSCR1	CATSCR2	CATSCR3	FTLB1	CRITB1	CONF1	FTLA1	CRITA1	C1
60	60	2	0	0	0	0	0	0	1	0	0	0	2	2	1	200	200	50	2	2	2	2	2	2	8	0	0	0	0	1	0	0	0	0	1	25	3	1	1	2	7	9	3	4	5
61	61	2	0	0	0	0	0	0	1	0	0	0	2	2	1	200	200	50	2	3	1	6	2	2	9	0	0	0	0	1	0	0	0	0	1	65	4	4	5	3	3	6	3	3	.
62	62	2	0	0	0	0	0	0	1	0	0	0	2	2	1	200	200	50	2	4	1	5	5	5	2	0	0	0	1	1	0	0	0	0	1	65	6	4	3	.	.	.	.	.	.
63	63	2	0	0	0	0	0	0	1	0	0	0	2	2	1	200	200	50	3	2	2	2	2	1	9	0	0	0	0	1	0	0	0	0	1	55	4	3	4	2	7	7	3	2	2
64	64	2	0	0	0	0	0	0	1	0	0	0	2	2	2	200	200	200	2	3	3	4	3	2	10	0	0	0	0	1	0	0	0	0	1	45	5	2	2	3	1	5	1	7	5
65	65	2	0	0	0	0	0	0	1	0	0	0	1	1	1	50	50	50	2	5	1	5	5	2	10	0	0	0	0	1	0	0	0	0	1	35	2	3	2	2	6	9	2	5	0
66	66	2	0	0	0	0	0	0	1	0	0	0	2	2	1	200	200	50	2	1	1	6	1	1	9	0	0	0	0	1	0	0	0	0	1	40	4	2	2	1	7	8	2	6	2
67	67	2	0	0	0	0	0	0	1	0	0	0	1	1	1	50	50	50	2	1	1	6	4	2	10	0	0	0	0	1	0	0	0	0	1	50	5	4	1	2	3	9	3	2	5
68	68	2	0	0	0	0	0	0	1	0	0	0	1	1	1	50	50	50	2	2	1	6	6	2	10	0	0	0	0	1	0	0	0	0	1	60	6	3	3	1	7	10	3	2	5

STUDENT	TOTINQ1	MAXDT1	TOTRAK1	UNTRAK1	TOCT1	CORINQ1	KEY1	FTLB2	CRITB2	CONF2	FTLA2	CRITA2	C2	TOTINQ2	MAXDT2	TOTRAK2	UNTRAK2	TOCT2	CORINQ2	KEY2	FTLB3	CRITB3	CONF3	FTLA3	CRITA3	C3	TOTINQ3
60	3	9	1	1	3	4	Y	3	3	3	3	2	0	16	40	5	3	0	0	N	3	2	9	3	2	5	11
61	12	42	7	4	1	4	Y	3	3	6	3	4	.	15	44	8	4	3	2	N	1	7	8	3	5	.	31
62	0	0	.	.	.	.		3	5	8	3	5	0	3	19	2	2	1	2	N	3	4	8	3	5	0	5
63	7	57	2	2	1	5	Y	3	3	5	3	3	5	9	75	8	5	2	2	Y	3	5	10	3	5	5	10
64	26	22	9	5	2	6	Y	3	1	5	3	3	0	2	9	1	1	1	2	N	2	6	4	2	5	2	15
65	3	4	1	1	1	3	N	2	6	9	3	3	0	5	14	1	1	1	5	N	3	2	8	3	1	5	8
66	6	10	2	2	2	5	Y	3	1	10	3	6	0	35	49	20	4	8	8	N	1	7	5	2	7	0	25
67	10	25	5	3	2	2	Y	3	1	7	3	4	0	20	33	12	4	4	4	N	2	4	2	3	5	2	31
68	4	9	1	1	1	4	Y	1	2	1	3	5	0	10	66	4	3	0	0	N	3	2	7	3	4	0	16

STUDENT	MAXDT3	TOTRAK3	UNTRAK3	TOCT3	CORINQ3	KEY3	FTLB4	CRITB4	CONF4	FTLA4	CRITA4	C4	TOTINQ4	MAXDT4	TOTRAK4	UNTRAK4	TOCT4
60	22	3	3	1	4	Y	3	1	10	3	1	2	11	32	4	4	1
61	22	15	6	2	2	N	3	1	10	3	2	.	9	20	3	3	1
62	36	2	2	0	0	N	3	5	9	3	2	2	7	30	3	3	1
63	21	4	4	1	3	Y	3	3	10	3	3	2	2	12	2	2	1
64	39	9	4	1	1	N	3	1	2	3	2	5	28	28	9	5	2
65	16	4	3	1	3	Y	3	3	6	3	1	5	9	18	2	2	1
66	44	10	4	0	0		2	7	10	3	5	2	4	8	3	3	1
67	30	18	7	1	1	N	2	3	8	3	2	2	16	20	7	4	1
68	13	10	6	1	1	N	3	5	6	3	4	2	10	49	4	3	0

Table 3-5. Master Data Table (continued)

ORIGINAL PAGE IS
OF POOR QUALITY

STUDENT	CORINQ4	KEY4	INPTR1	DIFT1	INPTR2	DIFT2	INPTR3	DIFT3	INPTR4	DIFT4	MEAN1	VAR1	MEAN2	VAR2	MEAN3	VAR3	MEAN4
50	2	N	3.00000	0	3.20000	2	3.66667	0	2.75000	0	6.6667	4.333	14.0625	132.196	8.4545	28.473	11.2727
51	3	Y	1.71429	3	1.87500	4	2.06667	9	3.00000	0	10.5000	183.545	10.9333	130.210	6.6452	34.170	6.7778
52	2	N	.	.	1.50000	0	2.50000	0	2.33333	0	.	.	9.3333	72.333	14.8000	195.700	8.8571
53	1	N	3.50000	0	1.12500	3	2.50000	0	1.00000	0	19.5714	361.619	25.3333	416.500	9.2000	55.511	9.0000
54	5	Y	2.88889	4	2.00000	0	1.66667	5	3.11111	4	7.3846	42.806	7.0000	8.000	9.5333	80.124	5.6071
55	4	Y	3.00000	0	5.00000	0	2.00000	1	4.50000	0	3.0000	1.000	8.2000	34.200	6.1250	25.268	5.6667
56	2	N	3.00000	0	1.75000	16	2.50000	6	1.33333	0	6.5000	16.300	6.2857	85.563	9.4000	117.417	6.0000
57	1	N	2.00000	2	1.66667	8	1.72222	11	2.28571	3	6.1000	55.656	10.2500	125.039	7.7419	43.531	5.4500
58	0	N	4.00000	0	2.50000	1	1.60000	4	2.50000	1	4.0000	12.000	16.3000	390.678	5.1875	10.696	12.7000

STUDENT	VAR4	MEAN5	VAR5	SCEN	MDELTAT	TOTRAK	UNIQTRAK	TOCT	CORINQ	TOTINQ	ZT	AVCTOTRK	AVCUNIQT	AVCTOCT	AVCCORIN	AVCTOTIN	AVCZT	INPTRT
50	116.618	14.5833	137.90	5	10.1141	13	11	5	10	41	0.92308	2.6	2.20	1.0	2.00	8.2000	0.184615	3.15385
51	42.694	9.1538	223.58	5	8.7141	33	17	7	11	67	.	6.6	3.40	1.4	2.20	13.4000	.	2.03030
52	103.143	15.7857	355.10	4	10.9968	.	.	.	.	15	.	.	.	.	.	3.7500	.	.
53	18.000	15.7333	192.21	5	15.7762	16	13	5	11	28	0.87500	3.2	2.60	1.0	2.20	5.6000	0.175000	1.75000
54	32.321	6.9000	52.78	5	7.3813	28	15	6	14	71	0.42857	5.6	3.00	1.2	2.80	14.2000	0.085714	2.53571
55	24.250	7.0769	35.51	5	5.7479	8	7	4	15	25	1.25000	1.6	1.40	0.8	3.00	5.0000	0.250000	3.12500
56	4.667	11.3846	268.76	5	7.0464	35	13	11	15	70	0.11429	7.0	2.60	2.2	3.00	14.0000	0.022857	2.00000
57	28.366	34.3939	5215.06	5	7.3855	42	18	8	8	77	0.21429	8.4	3.60	1.6	1.60	15.4000	0.042857	1.83333
58	242.011	10.2414	159.90	5	9.5469	19	13	2	5	40	0.36842	3.8	2.60	0.4	1.00	8.0000	0.073684	2.10526

Table 3-5. Master Data Table (continued)

STUDENT	AVCINPTR	DIFTT	AVCDIFTT	TOTCOR	PTOTCOR	SETLOC	TTLOC	TCRITBEF	TCRITAF	MEANDT	VARDT	MEANPA	VARPA	TOTINQDD	TOTAIRP	UNIQAIRP	MINQAIR	VINQAIR	YN	SELEC
60	0.630769	2	0.40	12	0.480000	5.29832	5.29832	13	9	4.0000	2.267	12.500	44.650	16	6	5	2.670	1.870	1	3
61	0.406061	16	3.20	.	.	5.29832	5.29832	14	14	3.7400	8.930	12.710	109.900	23	7	7	3.280	2.900	1	1
62	.	.	.	2	0.100000	5.29832	5.29832	.	.	3.4400	5.670	17.200	87.200	18	5	5	3.600	4.300	1	3
63	0.350000	3	0.60	14	0.560000	5.29832	5.29832	18	13	5.6110	14.490	18.670	10.330	18	3	3	6.000	0.000	1	12
64	0.507143	13	2.60	12	0.480000	5.29832	5.29832	9	17	2.7000	1.597	13.570	43.000	43	9	9	4.780	0.690	1	3
65	0.625000	1	0.20	10	0.400000	3.91202	3.91202	17	10	3.3900	3.976	12.570	33.619	23	7	7	3.280	1.570	1	3
66	0.400000	22	4.40	4	0.160000	5.29832	5.29832	22	24	2.6670	3.885	13.625	39.696	30	8	6	3.750	9.640	1	1
67	0.366667	24	4.80	9	0.360000	3.91202	3.91202	11	13	5.8750	25.850	13.330	5.333	16	3	3	5.330	1.330	1	6
68	0.421053	6	1.20	7	0.280000	3.91202	3.91202	16	15	4.8460	8.141	19.500	243.667	13	4	3	3.250	4.920	1	6

Table 3-5. Master Data Table (continued)

STUDENT	STUDENT	CERT	RAT1	RAT2	RAT3	RAT4	RAT5	RAT6	RAT7	RAT8	RAT9	RAT10	TT	SET	IT	TTA	SETA	ITA	SO	BI	PIC	IFR	INST	AGE	HIST	CUR1	CUR2	CUR3	CUR4	CUR5	PRI1	PRI2	PRI3	PRI4	PRI5	SCORE	CATSCR1	CATSCR2	CATSCR3	FTLB1	CRITB1	CONF1	FTLA1	CRITA1	C1	TOTINQ1	MAXDT1	TOTRAK1	UNTRAK1	TOCT1	CORINQ1	KEY1	FTLB2	CR!TB2	CONF2
69	69	3	0	0	0	0	1	1	1	0	0	0	4	4	1	750	750	50	3	5	1	1	1	2	9	0	0	1	1	1	0	0	1	0	0	70	4	6	4	1	6	9	2	4	2	4	.	2	2	1	3	N	3	4	9
70	70	3	0	0	0	0	1	1	1	1	1	1	10	9	5	15000	7500	1500	1	4	1	1	1	5	4	0	0	1	1	1	0	0	0	1	0	75	6	3	6	1	7	9	2	1	2	5	32	2	2	0	0	N	2	1	7
71	71	3	0	0	0	0	1	0	0	1	0	0	3	3	2	400	400	200	2	2	1	2	2	1	9	0	0	0	1	1	0	0	0	0	1	55	4	4	3	.	.	.	.	.	.	0	0	.	.	.	.	.	3	3	7
72	72	4	0	0	0	0	1	1	1	1	0	0	6	6	3	2500	2500	400	3	2	1	1	1	2	8	0	0	1	0	0	0	0	1	0	0	75	5	5	5	.	.	.	.	.	.	0	0	.	.	.	.	.	3	5	8
73	73	3	0	0	0	0	1	1	1	1	0	0	4	4	2	750	750	200	2	3	1	1	1	2	9	0	0	1	1	1	0	0	0	1	0	40	3	1	4	.	.	.	.	.	.	0	0	.	.	.	.	.	3	3	5
75	75	3	0	0	0	0	1	0	1	1	0	0	6	2	4	2500	200	750	1	6	6	6	6	3	7	0	1	0	0	0	0	1	0	0	0	30	0	4	2	1	5	8	3	1	2	10	26	3	3	0	0	N	3	5	5
76	76	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	0	.	.	.	.	.	2	4	3
77	77	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	0	.	.	.	.	.	3	5	9
78	78	3	0	0	0	1	1	1	1	1	0	0	6	5	3	2500	1500	400	1	1	1	1	1	3	7	1	1	1	0	1	0	1	0	0	1	70	6	5	3	.	.	.	.	.	.	0	0	.	.	.	.	.	3	6	7

STUDENT	FTLA2	CRITA2	C2	TOTINQ2	MAXDT2	TOTRAK2	UNTRAK2	TOCT2	CORINQ2	KEY2	FTLB3	CRITB3	CONF3	FTLA3	CRITA3	C3	TOTINQ3	MAXDT3	TOTRAK3	UNTRAK3	TOCT3	CORINQ3	KEY3	FTLB4	CRITB4	CONF4	FTLA4	CRITA4	C4	TOTINQ4	MAXDT4	TOTRAK4	UNTRAK4	TOCT4	CORINQ4	KEY4	INPTR1	DIFT1	INPTR2	DIFTR2	INPTR3	DIFTR3	INPTR4
69	3	4	5	4	.	3	3	1	3	N	3	5	10	3	5	5	5	.	4	3	1	0	N	3	2	9	3	2	5	3	.	1	1	1	3	Y	2.00000	0	1.33333	0	1.25000	1	3.00000
70	3	5	0	6	120	5	4	1	1	N	1	7	7	3	4	2	7	106	5	4	1	1	N	3	2	10	3	1	5	2	50	1	1	1	2	Y	2.50000	0	1.20000	1	1.40000	1	2.00000
71	3	3	5	34	44	21	5	4	4	Y	3	5	10	3	5	5	8	37	3	3	1	4	Y	3	5	8	3	5	0	6	53	4	3	2	4	N	.	.	1.61905	16	2.66667	0	1.50000
72	3	5	5	3	33	2	2	1	1	Y	2	6	5	3	4	0	17	90	8	3	9	0	N	2	5	9	3	5	2	10	112	6	5	2	4	N	.	.	1.50000	0	2.12500	5	1.66667
73	3	6	0	28	250	17	5	1	1	N	2	6	8	3	5	4	18	274	6	5	1	1	N	2	7	10	3	4	2	6	127	3	3	0	0	N	.	.	1.64706	12	3.00000	1	2.00000
75	2	5	0	22	27	6	3	0	0	N	3	3	9	3	2	5	15	21	7	5	1	6	Y	3	1	8	3	1	5	16	19	2	2	1	5	Y	3.33333	0	3.66667	3	2.14286	2	8.00000
76	2	2	0	21	31	10	5	3	4	Y	.	.	.	.	.	.	0	0	.	.	.	.	.	.	.	.	.	.	.	0	0	.	.	.	.	.	.	.	2.10000	5	.	.	.
77	3	5	5	11	33	7	4	3	3	Y	.	.	.	.	.	.	0	0	.	.	.	.	.	.	.	.	.	.	.	0	0	.	.	.	.	.	.	.	1.57143	3	.	.	.
78	3	7	0	8	26	3	3	1	3	N	3	5	9	3	5	5	11	17	3	3	1	7	Y	2	4	8	2	4	5	14	17	5	3	2	9	Y	.	.	2.66667	0	3.66667	0	2.80000

Table 3-5. Master Data Table (continued)

STUDENT	DIFT4	MEAN1	VAR1	MEAN2	VAR2	MEAN3	VAR3	MEAN4	VAR4	MEAN5	VAR5	SCEN	MDELTAT	TOTRAK	UNIQTRAK	TOCT	CORINQ	TOTINQ	ZT	AVCTOTRK	AVCUNIQT	AVCTOCT	AVCCORIN
69	0	.	.	.	.	.	.	.	.	.	.	5	.	10	9	4	9	16	1.70000	2.0	1.80	0.8	1.80
70	0	.	.	.	.	.	.	.	.	.	.	5	.	13	11	3	4	20	0.69231	2.6	2.20	0.6	0.80
71	1	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	48	.	.	.	.	.
72	1	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	30	.	.	.	.	.
73	0	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	52	.	.	.	.	.
75	0	10.1000	50.322	8.4091	47.968	7.2667	36.924	6.81250	30.429	.	.	4	8.1471	18	13	2	11	63	0.66667	4.5	3.25	0.5	2.75
76	.	.	.	8.7143	89.614	.	.	.	.	.	.	2	8.7143	.	.	.	.	21	.	.	.	.	.
77	.	.	.	12.2727	106.818	.	.	.	.	.	.	2	12.2727	.	.	.	.	11	.	.	.	.	.
78	2	.	.	10.2500	63.357	6.9091	16.491	6.50000	18.115	.	.	3	7.8864	.	.	.	.	33	.	.	.	.	.

STUDENT	AVCTOTIN	AVCZT	INPTRT	AVCINPTR	DIFTT	AVCDIFTT	TOTCOR	PTOTCOR	SETLOG	TTLOG	TCRITBEF	TCRITAF	MEANDT	VARDT	MEANPA	VARPA	TOTINQDD	TOTAIRP	UNIQAIRP	MINQAIR	VINQAIR	YN	SELEC
69	3.2000	0.340000	1.60000	0.320000	1	0.20	17	0.680000	6.62007	6.62007	17	15	2.6670	1.8800	10.36	38.45	24	11	8	2.180	2.160	1	12
70	4.0000	0.138462	1.53846	0.307692	2	0.40	9	0.360000	8.92266	9.61581	17	11	5.4500	8.8700	9.00	8.00	11	2	2	5.500	0.500	1	1
71	16.0000	.	.	.	.	.	10	0.666667	5.99146	5.99146	.	.	.	.	.	.	.	.	.	.	.	.	.
72	10.0000	.	.	.	.	.	7	0.466667	7.82405	7.82405	.	.	.	.	.	.	.	.	.	.	.	.	.
73	17.3333	.	.	.	.	.	6	0.400000	6.62007	6.62007	.	.	.	.	.	.	.	.	.	.	.	.	.
75	15.7500	0.166667	3.50000	0.875000	5	1.25	12	0.600000	5.29832	7.82405	14	9	4.3300	5.0700	13.50	4.50	6	2	2	3.000	2.000	1	1
76	10.5000	.	.	.	.	.	0	0.000000	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
77	5.5000	.	.	.	.	.	5	0.500000	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
78	11.0000	.	.	.	.	.	10	0.666667	7.31322	7.82405	.	.	3.0417	5.5200	10.55	46.87	24	11	9	2.182	1.964	1	3

Table 3-5. Master Data Table (continued)

STUDENT	STUDENT	CERT	RAT1	RAT2	RAT3	RAT4	RAT5	RAT6	RAT7	RAT8	RAT9	RATI0	TT	SET	IT	TTA	SETA	ITA	SO	BI	PIC	IFR	INST	AGE	HIST	CUR1	CUR2	CUR3	CUR4	CUR5	PRI1	PRI2	PRI3	PRI4	PRI5
79	79	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
80	80	4	0	0	0	0	1	0	1	1	0	0	7	5	5	3500	1500	1500	2	4	1	1	1	2	8	1	0	1	1	1	0	0	1	0	0
81	81	2	0	0	0	0	0	0	1	0	0	0	2	2	1	200	200	50	3	5	1	6	6	3	8	0	0	0	0	1	0	0	0	0	1
82	82	3	0	1	1	0	0	0	1	0	1	0	9	5	1	7500	1500	50	3	5	1	6	6	5	6	0	0	0	0	1	0	0	0	0	1
83	83	2	0	0	0	0	0	0	1	0	0	0	2	2	1	200	200	50	2	4	1	1	3	2	9	0	0	0	0	1	0	0	0	0	1
84	84	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

STUDENT	SCORE	CATSCR1	CATSCR2	CATSCR3	FTLB1	CRITB1	CONF1	FTLA1	CRITA1	C1	TOTINQ1	MAXDT1	TOTRAK1	UNTRAK1	TROCT1	CORINQ1	KEY1	FTLB2	CRITB2	CONF2
79	.	.	.	.	.	.	.	.	.	.	0	0	.	.	.	.		2	6	6
80	70	4	5	5	2	2	10	2	2	5	6	33	4	3	2	3	Y	2	2	5
81	30	2	2	2	.	.	.	.	.	.	0	0	.	.	.	.		3	7	1
82	60	6	5	1	.	.	.	.	.	.	0	0	.	.	.	.		2	4	5
83	60	3	4	5	.	.	.	.	.	.	0	0	.	.	.	.		2	4	6
84	.	.	.	.	.	.	.	.	.	.	0	0	.	.	.	.		2	7	5

STUDENT	FTLA2	CRITA2	C2	TOTINQ2	MAXDT2	TOTRAK2	UNTRAK2	TROCT2	CORINQ2	KEY2	FTLB3	CRITB3	CONF3	FTLA3	CRITA3	C3	TOTINQ3	MAXDT3	TOTRAK3	UNTRAK3	TROCT3	CORINQ3	KEY3
79	1	6	0	23	24	11	5	1	1	N	.	.	.	.	.	.	0	0	.	.	.	.	
80	2	2	5	17	76	9	5	3	4	Y	2	2	10	2	2	5	5	20	2	2	1	4	Y
81	2	4	0	29	86	9	5	0	0	N	2	4	7	2	5	0	57	22	32	7	4	6	N
82	3	2	0	33	44	19	5	3	5	Y	2	5	9	2	4	5	4	62	1	1	1	4	Y
83	1	6	0	4	41	3	3	1	1	N	2	5	9	2	4	5	11	12	3	3	1	6	Y
84	3	1	0	21	36	8	4	1	1	N	.	.	.	.	.	.	0	0	.	.	.	.	

STUDENT	FTLB4	CRITB4	CONF4	FTLA4	CRITA4	C4	TOTINQ4	MAXDT4	TOTRAK4	UNTRAK4	TROCT4	CORINQ4	KEY4	INPTR1	DIFT1	INPTR2	DIFT2	INPTR3	DIFT3	INPTR4	DIFT4
79	.	.	.	.	.	.	0	0	.	.	.	.		.	.	2.09091	6	.	.	.	.
80	2	6	10	2	6	2	26	15	11	5	4	6	N	1.5	1	1.88889	4	2.50000	0	2.36364	6
81	2	3	9	2	5	2	33	63	9	5	1	1	N	.	.	3.22222	4	1.78125	25	3.66667	4
82	2	5	6	3	1	2	6	11	1	1	0	0	N	.	.	3.30000	5	4.00000	0	6.00000	0
83	2	6	5	3	5	2	24	66	9	4	2	4	N	.	.	1.33333	0	3.66667	0	2.66667	5
84	.	.	.	.	.	.	0	0	.	.	.	.		.	.	2.62500	4	.	.	.	.

Table 3-5. Master Data Table (continued)

ORIGINAL PAGE IS OF POOR QUALITY

STUDENT	MEAN1	VAR1	MEAN2	VAR2	MEAN3	VAR3	MEAN4	VAR4	MEAN5	VAR5	SCEN	MDELTAT	TOTRAK	UNIQTRAK	TOCT	CORINQ	TOTINQ	ZT	AVCTOTRK	AVCUNIQT	AVCTOCT	AVCCORIN
79	.	.	6.6957	51.858	.	.	.	.	.	.	2	6.6957	.	.	.	.	23	.	.	.	.	.
80	10.1667	136.167	10.5000	322.133	7.0000	21.500	4.00000	17.840	.	.	4	7.9167	26	15	10	17	54	0.653846	6.5	3.75	2.5	4.25
81	.	.	8.2414	289.547	3.9643	22.617	6.78788	135.110	.	.	3	6.33[illegible]	.	.	.	.	119	.	.	.	.	.
82	.	.	11.6061	588.746	21.0000	767.333	3.33333	3.067	.	.	3	11.9798	.	.	.	.	43	.	.	.	.	.
83	.	.	25.[illegible]	282.917	4.4545	13.473	9.50000	186.870	.	.	3	13.0682	.	.	.	.	39	.	.	.	.	.
84	.	.	11.1905	83.162	.	.	.	.	.	.	1	11.1965	.	.	.	.	21	.	.	.	.	.

STUDENT	AVCTOTIN	AVCZT	INPTRT	AVCINPTR	DIFTT	AVCDIFTT	TOTCOR	PTOTCOR	SETLOC	TTLOC	TCRITBEF	TCRITAF	MEANDT	VARDT	MEANPA	VARPA	TOTINQDD	TOTAIRP	UNIQAIRP	MINQAIR	VINQAIR	YN	SELEC
79	11.5000	.	.	.	.	.	0	0.000000	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
80	13.5000	0.163462	2.07692	0.519231	11	2.75	17	0.850000	7.31322	8.16052	12	12	4.000	8.2500	14.4	20.8	17	5	4	3.400	3.800	1	14
81	39.6667	.	.	.	.	.	2	0.133333	5.29832	5.29832	.	.	.	.	.	.	.	.	.	.	.	.	.
82	14.3333	.	.	.	.	.	7	0.466667	7.31322	8.92266	.	.	.	.	.	.	.	.	.	.	.	.	.
83	13.0000	.	.	.	.	.	7	0.466667	5.29832	5.29832	.	.	2.615	1.0897	6.0	13.0	13	3	3	4.333	2.333	1	5
84	21.0000	.	.	.	.	.	0	0.000000	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Table 3-5. Master Data Table (continued)

ORIGINAL PAGE IS
OF POOR QUALITY

ORIGINAL PAGE IS
OF POOR QUALITY

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
SCORE	38	56.57894737	14.09932254	25.00000000	80.0000000
CATSCR1	38	4.21052632	1.43617161	0.00000000	7.0000000
CATSCR2	38	3.57894737	1.26558562	1.00000000	6.0000000
CATSCR3	38	3.52631579	1.51990117	1.00000000	6.0000000
TTA	38	1653.94736842	2861.28353307	50.00000000	15000.0000000
SETA	38	932.89473684	1341.15099397	50.00000000	7500.0000000
ITA	38	256.57894737	409.04817872	50.00000000	1500.0000000
TOTCOR	41	9.43902439	4.98020472	0.00000000	20.0000000
PTOTCOR	41	0.46691057	0.23758436	0.00000000	1.0000000
TOTRAK1	30	3.33333333	2.02285789	1.00000000	9.0000000
TOTRAK2	42	6.76190476	4.74115106	1.00000000	21.0000000
TOTRAK3	37	7.13513514	6.01462182	1.00000000	32.0000000
TOTRAK4	38	5.76315789	4.13576497	1.00000000	18.0000000
TOTRAK	29	22.10344828	10.68491870	7.00000000	52.0000000
AVGTOTRK	29	4.98275862	2.34114120	1.60000000	10.4000000
UNTRAK1	30	2.56666667	1.13512367	1.00000000	5.0000000
UNTRAK2	42	3.57142857	1.17167500	1.00000000	5.0000000
UNTRAK3	37	4.00000000	1.58113883	1.00000000	7.0000000
UNTRAK4	38	3.34210526	1.27928011	1.00000000	5.0000000
UNIQTRAK	29	13.31034483	3.14078526	7.00000000	20.0000000
AVGUNIQT	29	3.00862069	0.78718179	1.40000000	4.2500000
DIFT1	30	0.76666667	1.07264846	0.00000000	4.0000000
DIFT2	42	3.19047619	3.98312352	0.00000000	16.0000000
DIFT3	37	3.13513514	4.80833860	0.00000000	25.0000000
DIFT4	38	2.42105263	3.24355143	0.00000000	13.0000000
DIFTT	29	8.79310345	8.12570573	0.00000000	32.0000000
AVGDIFTT	29	1.97413793	1.73424648	0.00000000	6.4000000
TOCT1	30	1.40000000	0.89442719	0.00000000	3.0000000
TOCT2	42	1.54761905	1.59576239	0.00000000	8.0000000
TOCT3	37	1.00000000	0.74535599	0.00000000	4.0000000
TOCT4	38	1.76315789	1.28261158	0.00000000	5.0000000
TOCT	29	5.79310345	2.69098111	2.00000000	11.0000000
AVGTOCT	29	1.31896552	0.64978208	0.40000000	2.5000000
CORINQ1	30	3.23333333	2.16051292	0.00000000	7.0000000
CORINQ2	42	2.02380952	1.91894401	0.00000000	8.0000000
CORINQ3	37	3.18918919	2.43627491	0.00000000	7.0000000
CORINQ4	38	4.28947368	2.99466097	0.00000000	12.0000000
CORINQ	29	12.82758621	4.37581801	4.00000000	20.0000000
AVGCORIN	29	2.97068966	1.23009271	0.80000000	5.0000000
TOTINQ1	42	6.11904762	5.73479913	0.00000000	26.0000000
TOTINQ2	42	15.21428571	9.26186968	2.00000000	35.0000000
TOTINQ3	42	15.09523810	12.02803539	0.00000000	57.0000000
TOTINQ4	42	13.90476190	10.66063999	0.00000000	40.0000000
TOTINQ	42	50.33333333	25.20517433	11.00000000	119.0000000
AVGTOTIN	42	13.30317460	6.72606188	3.20000000	39.6666667
INPTR1	30	2.93399471	1.15045361	1.50000000	6.0000000
INPTR2	42	2.45054497	0.96552683	1.12500000	5.0000000
INPTR3	37	2.86997423	1.99915980	1.25000000	14.0000000
INPTR4	38	2.97505015	1.49464427	1.00000000	8.0000000
INPTRT	29	2.62469663	0.74169520	1.53846154	5.0000000
AVGINPTR	29	0.60017866	0.20677399	0.30769231	1.2500000
ZT	28	0.66808890	0.38456833	0.11428571	1.7000000
AVGZT	28	0.15098955	0.08589887	0.02285714	0.3571429

Table 3-6. STATISTICS FOR PERFORMANCE MEASURES

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
MEAN1	28	10.62921245	5.73186168	3.00000000	26.4444444
MEAN2	37	12.14518399	6.28365104	5.33333333	28.3333333
MEAN3	32	8.40835212	3.96574182	3.70731707	21.0000000
MEAN4	33	7.36637337	2.95669341	3.33333333	13.8000000
MDELTAT	37	9.66473853	2.73333221	5.74791667	15.7761905
VAR1	28	102.85220992	121.48373560	1.00000000	403.7777778
VAR2	37	232.78053447	297.52487384	8.00000000	1638.0000000
VAR3	32	96.05828707	157.77832889	2.45555556	767.3333333
VAR4	33	96.28052575	136.12501031	3.06666667	638.7000000

Table 3-6. (continued)

list in order to allow all forty-three subjects' data to be considered in the regression analysis. Since the majority of subjects completed scenarios 2, 3, and 4, all calculations for the independent performance measures were limited to these three. Given the criteria just mentioned above, only knowledge score and total correctness (TOTCORR = C2 + C3 + C4) can be appropriately modeled.

When correctness scores on individual scenarios are examined, C1-C4, several interesting conclusions appear. Knowledge subscores are good predictors for C2 and C4 only. A single experience variable, source of instrument training, shows up in C3 prediction. The total number of unique tracks and the total number of times the subject was on the correct track are positive predictors in either scenarios 1 or 2. The lower DIFTT (total tracks - total unique tracks), the higher the correctness score is on scenario 1. The correctness score on scenario 3 increases as the total number of inquiries decreases. As might be expected, the lower the variance on delta (decision and response) time, the higher the correctness score on scenario number 4. What was surprising was the absence of such occurrences over all four correctness scores. This may be due in part because good performance on one scenario does not necessarily translate into good performance on all four scenarios as verified by the learning experiment.

For Z_t the ratio of total correct to total number of tracks, it was revealed that as both DIFTT (TOTRAK - UNIQTRAK) and the total number of inquiries diminish, Z_t rises. A pilot's source of instrument training seems to augment Z_t. Both Z_t and the total number of inquiries are negative predictors of mean time between inquiries (MDELTAT).

Table 3-7. SUMMARY OF STEPWISE PREDICTIONS

PREDICTOR VARIABLE			BIOGRAPHICAL & EXPERIENCE	KNOWLEDGE	INDEPENDENT PERFORMANCE VARS.
	R^2	N			
			SET TT SO AGE	CATSCR1 SCORE CATSCR2 CATSCR3	C1-C4, INPTRT, DIFTT, MEAN1-4, VAR1-4, TOTINQ, TOTRAK, UNIQTRAK, CORINQ, TOCT MDELTAT, TOTCOR, ET, VDELTAT
C1	.65	26			C2 (.0031)* UNIQTRAK (.0001) DIFTT (.0847)* C3 (.0072)* C4 (.0600)*
C2	.80	26		CATSCR2 (.0527)* CATSCR3 (.0011)	TOCT (.0014) C4 (.0024)* VAR1 (.0011) MEAN3 (.0001)*
C3	.93	26	SO (.0001)*		C1 (.0536)* UNIQTRAK (.0001) TOTINQ (.0021)* MEAN1 (.0169) VAR4 (.0162)*
C4	.66	26		CATSCR3 (.0044)	C2 (.0066)* MEAN 1 (.0139) MEAN 2 (.0103)* VAR 4 (.0366)*
ZT	.79	26	SO (.0144)	CATSCR1 (.0550)*	DIFTT (.0696)* TOTINQ (.0259)* MEAN2 (.0195) VAR2 (.0739)
DELTAT	.64	26	SO (.0122) AGE (.0357)		C3 (.0041) ZT (.0016)* TOTINQ (.0091)*

*NEGATIVE B VALUE

Referring to Table 3-8 and recalling the procedure utilized in performing this set of regression analyses, certain intuitive results appear. The total number of unique tracks, the total number of times the subject is on the correct track, and the number of single engine hours are all positive predictors of pilot's knowledge survey score. The total number of tracks and knowledge score are inversely related.

As the total number of tracks and the total number of times the subject is on the correct track increase, total correctness (TOTCORR) will also increase. Total correctness will rise as DIFTT (total tracks - total unique tracks) decreases.

Tests On Data Partitions

Table 3-9 labeled "Summary of T-Test" shows a series of tests on extreme partitions of major independent and key dependent measures to determine if differences might exist between them. These extreme "cuts" were obtained from a cumulative frequency table furnished by SAS. The splits or cuts were made at the lower 25 percent quartile and at the upper 75 percent quartile on biographical measures involving flying time and age,.plus two performance measures, SCORE and TOTCOR. For example, the cumulative frequency table reveals that for this group of subjects the lower 25 percent have, at most, only one hundred hours of single engine flying experience, while the upper seventy-five percent have greater than 1,001 hours of single engine experience. Partitions were also made according to pilot classifications, i.e. private versus non-private, VFR rated versus IFR rated, military versus civilian, high recency versus low recency, and pleasure versus non-pleasure.

Table 3-8. SUMMARY OF STEPWISE PREDICTIONS

-based on Scen 2,3,4

PREDICTOR VARIABLE	R^2	N	BIOGRAPHICAL & EXPERIENCE	KNOWLEDGE	INDEPENDENT PERFORMANCE VARS.
SCORE	.51	35	SETLOG (.0034)		TOTRAK (.0009)* UNIQTRAK (.0109) C3 (.0776)* TOCT (.0078)
TOTCORR	.48	35		CATSCR1 (.0191)*	TOTRAK (.0934) DIFTT (.0125)* TOCT (.0004)

*NEGATIVE B VALUE

Table 3-9 Summary of T-test

Data partitions on Biographical & Experience and Key Dependent Measures	N	Test Variables			
		Variable	Prob>|T|	Higher Valued Group	N for spec. variable
		CATSCR1, CATSCR2, CATSCR3, SCORE, C1-C4, TOTCOR TOTRAK, UNIQTRAK, DIFTT, TOCT, CORINQ, TOTINQ, INPTRT, SETLOG, TTLOG, MEAN1-4, MPELTAT, VAR1-4, SO, ZT			
Low Single Engine Hrs. vs. High Single Engine Hrs.		CATSCR2	(.0361)	(1)	6 10
(0) ≤ 100	(0) 10	CATSCR3	(.0478)	(1)	6 10
(1) ≥ 1001	(1) 11	SCORE	(.0148)	(1)	6 10
		SETLOG	(.0001)	(1)	6 11
		TTLOG	(.0001)	(1)	6 11
		MEAN2	(.0365)	(1)	10 9
		VAR2	(.0391)	(1)	10 9
Low Total Hrs. vs. High Total Hrs.		CATSCR2	(.0176)	(1)	15 8
(0) ≤ 300	(0) 19	CATSCR3	(.0958)	(1)	15 8
(1) ≥ 2001	(1) 9	SCORE	(.0624)	(1)	15 8
		C1	(.0367)	(0)	11 6
		SETLOG	(.0001)	(1)	15 9
		TTLOG	(.0001)	(1)	15 9
Private vs. Non-Private Rating		CATSCR2	(.0090)	(1)	16 21
(0) Private	(0) 16	CATSCR3	(.0995)	(1)	16 21
(1) Commercial & Air Transport	(1) 22	SCORE	(.0334)	(1)	16 21
		TOTRAK	(.0761)	(0)	13 16
		UNIQTRAK	(.0745)	(0)	13 16
		SETLOG	(.0001)	(1)	16 22
		TTLOG	(.0001)	(1)	16 22

Table 3-9. (continued)

Young vs. Old (0) < 20 (1) ≥ 51	(0) 7 (1) 5	CATSCR1	(.0393)	(1)	3 5
		SCORE	(.0557)	(1)	3 5
IFR vs. VFR (0) IFR (1) VFR	(0) 21 (1) 21	CATSCR2	(.0587)	(0)	20 17
		CATSCR3	(.0787)	(0)	20 17
		SCORE	(.0582)	(0)	20 17
		TOTCOR	(.0447)	(0)	21 20
		SETLOG	(.0015)	(0)	21 17
		TTLOG	(.0001)	(0)	21 17
		VAR4	(.0987)	(1)	16 17
		SO	(.0488)	(1)	21 17
		PTOTCOR	(.0178)	(0)	21 20
Low Knowledge Score vs. High Knowledge Score (0) ≤ 45 (1) > 65	(0) 14 (1) 10	CATSCR1	(.0005)	(1)	9 10
		CATSCR2	(.0002)	(1)	9 10
		CATSCR3	(.0001)	(1)	9 10
		PTOTCOR	(.0585)	(1)	14 10
		C2	(.0700)	(1)	14 10
		TOTCOR	(.0324)	(1)	14 10
		SETLOG	(.0072)	(1)	10 10
		TTLOG	(.0183)	(1)	10 10
		MEAN1	(.0816)	(1)	7 7
		MDELTAT	(.0227)	(1)	13 7

Table 3-9. (continued)

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Civilian vs. Military					
(0) Civilian	(0) 32	C2	(.0674)	(0)	31 6
(1) Military	(1) 6	TOCT	(.0149)	(0)	24 5
		TTLOG	(.0021)	(1)	32 6
		VAR1	(.0427)	(0)	24 4
		VAR3	(.0100)	(0)	27 5
Low Total Correct vs. High Total Correct					
(0) ≤ 6	(0) 11	CATSCR2	(.0768)	(1)	7 9
(1) > 12	(1) 9	C1	(.0279)	(1)	3 9
		C2	(.0453)	(1)	10 9
		C3	(.0013)	(1)	6 9
		C4	(.0134)	(1)	6 9
		MEAN1	(.0150)	(1)	4 8
		MDELTAT	(.0629)	(1)	10 8
		ZT	(.0219)	(1)	3 9
Low Percentage Correct vs. High Percentage Correct					
(0) ≤ .35	(0) 11	C2	(.0282)	(1)	10 10
(1) > .60	(1) 10	C4	(.0145)	(1)	7 10
		CORINQ	(.0660)	(1)	6 8
		MEAN1	(.0058)	(1)	6 7
		VAR1	(.0987)	(1)	6 7
		ZT	(.0153)	(1)	5 8

Table 3-9. (continued)

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High Recency vs. Low Recency					
(0) Last 30 days	(0) 23	CATSCR2	(.0403)	(0)	18 10
(1) > 2 years	(1) 10	CATSCR3	(.0092)	(0)	18 10
		SCORE	(.0017)	(0)	18 10
		C3	(.0252)	(0)	18 9
		TOTRAK	(.0147)	(1)	14 8
		DIFTT	(.0100)	(1)	14 8
		TOTINQ	(.0017)	(1)	23 10
		SETLOG	(.0171)	(0)	19 10
		TTLOG	(.0277)	(0)	19 10
		MEAN2	(.0580)	(0)	19 10
		ZT	(.0661)	(0)	14 7
Pleasure vs. Non-pleasure					
(0) Airline					
Military	(0) 17	CATSCR3	(.0576)	(0)	17 20
Hired	(1) 21	SCORE	(.0471)	(0)	17 20
Business		C1	(.0241)	(1)	15 14
(1) Pleasure		SETLOG	(.0125)	(0)	17 21
		TTLOG	(.0004)	(0)	17 21

Thirty-one performance and experience variables were chosen as candidates for the t-test. The objective was to see if there was any significant difference between the means of the twenty-five percent quartile and the seventy-five percent quartile for the performance or experience measure in question.

Separating single engine experience revealed a higher knowledge survey score for pilots with over 1,001 hours versus those with less than one hundred hours. Total flying experience ($\leq$ 300 hours versus $\geq$ 2,001 hours) appeared to exhibit the same relationship to performance as did single engine flying experience. Splits on ratings revealed that commercial and ATP pilots tend to possess greater knowledge than do private pilots. Private pilots tend to use a larger number of total tracks and total unique tracks than do commercial or ATP pilots.

For training partitions, military training led to smaller variances on delta times (decision and response time) for scenarios 1 and 3. Civilian pilots tend to have fewer hours than do pilots with military training. However, civilian pilots attained a higher correctness score on scenario 2 (vacuum pump failure). The total number of times the subject is on the correct track is also higher for the civilian pilots.

A split on IFR versus VFR rated pilots disclosed that IFR airmen retain a higher knowledge survey score and greater total correctness than do VFR airmen.

When performance measures are split to get profiles of high score pilots versus low score pilots, some independent performance effects are noted. Higher knowledge scores (>65%) are associated with:

(a) higher single engine hours experience

(b) higher total flying experience

(c) higher correctness scores

(d) higher mean delta times

When the top and bottom quartile on correctness scores are examined, added independent performance results begin to appear. High total correctness (>12; >60%) is characterized by the following:

(a) higher knowledge scores on cockpit instrumentation and electrical systems

(b) a greater number of inquiries on the correct track

(c) higher mean delta times

Those pilots who submitted an instrument flight rules plan in the last thirty days are characterized by:

(a) higher knowledge scores

(b) a higher correctness score on scenario 3

(c) a higher ratio of total correct to total number of tracks (Z_t)

(d) greater total flying experience

(e) fewer total tracks

(f) fewer DIFTT

(g) fewer total inquiries

as opposed to those who have not done so in the past two years.

Pilots who fly mainly for pleasure tended to score better on scenario 1. However, this class of pilots showed less knowledge and less experience than people who fly mainly for airline, commercial, business, or military purposes. Airmen over fifty years of age achieved better knowledge scores than those under twenty years of age.

PIP Analysis

A Pilot Information Plot (PIP) was created for every subject on each diagnostic scenario attempted. These charts serve much the same purpose as the flow process charts long in vogue by industrial engineers. They provide a quick visualization of the information gathering style of a subject. One can tell at a glance which subjects have a systematic approach to collecting information and which seem to "shotgun" across the panel in search of any clue to the problem at hand. For example, one can see extremes in subject performance on scenario 2 from the PIPs presented and discussed in chapter 2 of this report.

It is also possible to compare performance of a single subject across all scenarios. For example, subject 42 is depicted in Figure 3-13 through 3-16. This subject has a very systematic search pattern which is similar for all four scenarios. He sought multiple data on a single track before switching. In three of the four he found the key element of information but in each case he elected to seek additional information to verify what at that point must have been an almost certain conclusion.

Subject 57 on the other hand exhibits an almost random data acquisition pattern. Figure 3-17 through 3-20 show evidence of many changes in tracks and a great number of inquiries. It appears as if this subject has no hypotheses to test but rather collects all the data possible in the time allotted before drawing any conclusions. This subject also returns to tracks and even to items within track many times. Yet in spite of this total immersion in data the subject did correctly diagnose two of the four scenarios taken simply by accidently discovering the key information element.

Figure 3-13: Pilot Information Plot For Scenario #1, Subject #42

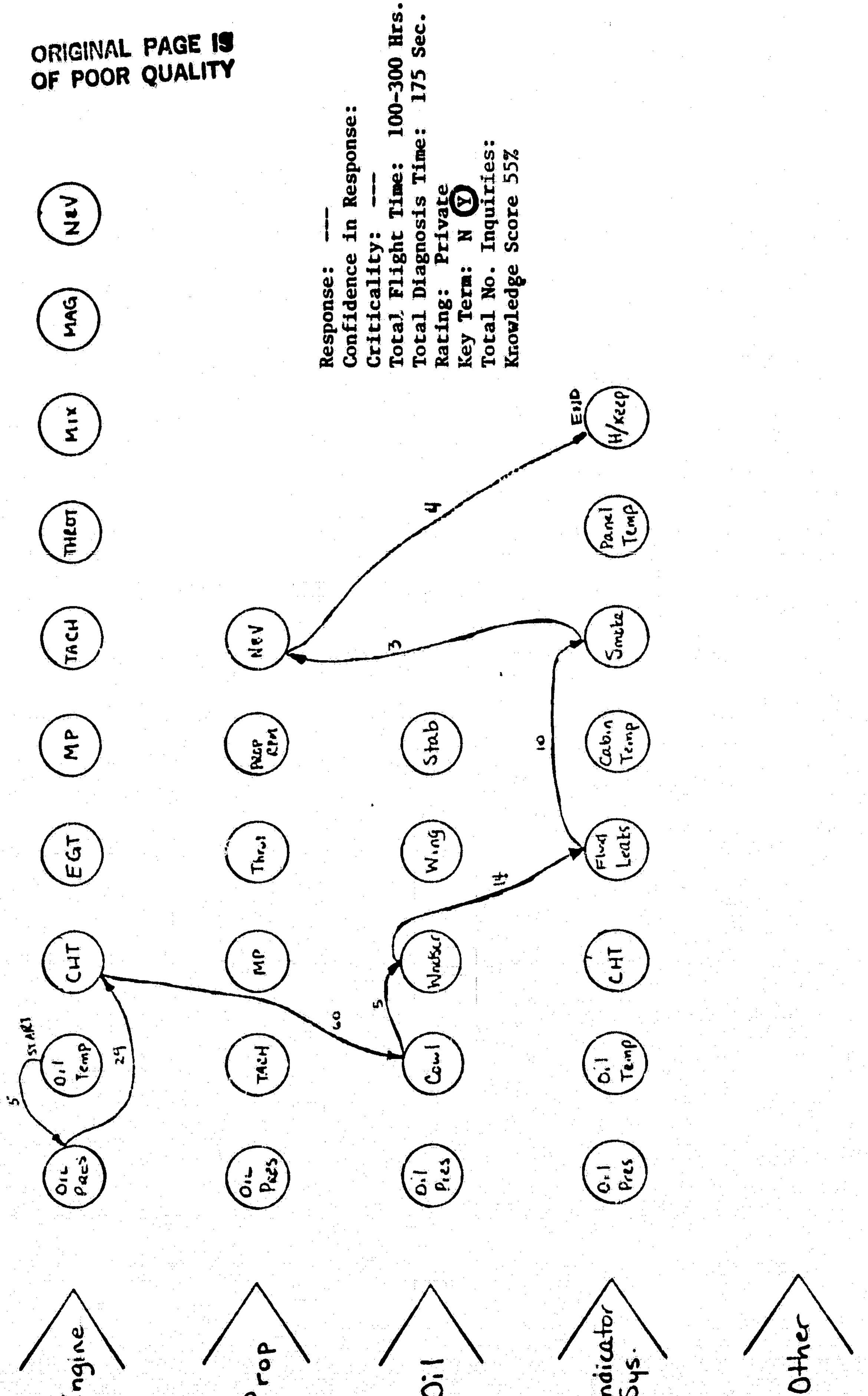
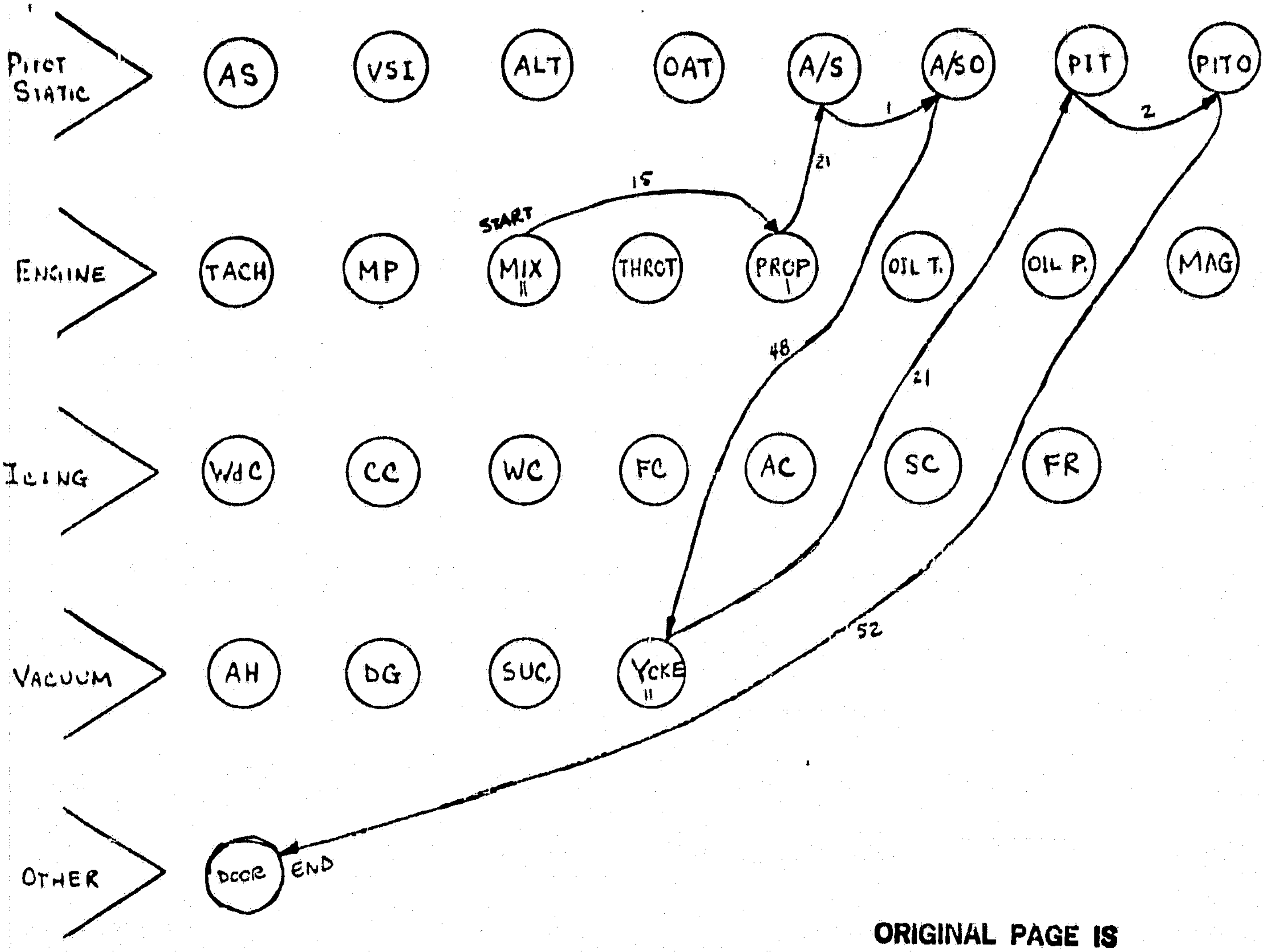


Figure 3-14: Pilot Information Plot For Scenario #2, Subject #42



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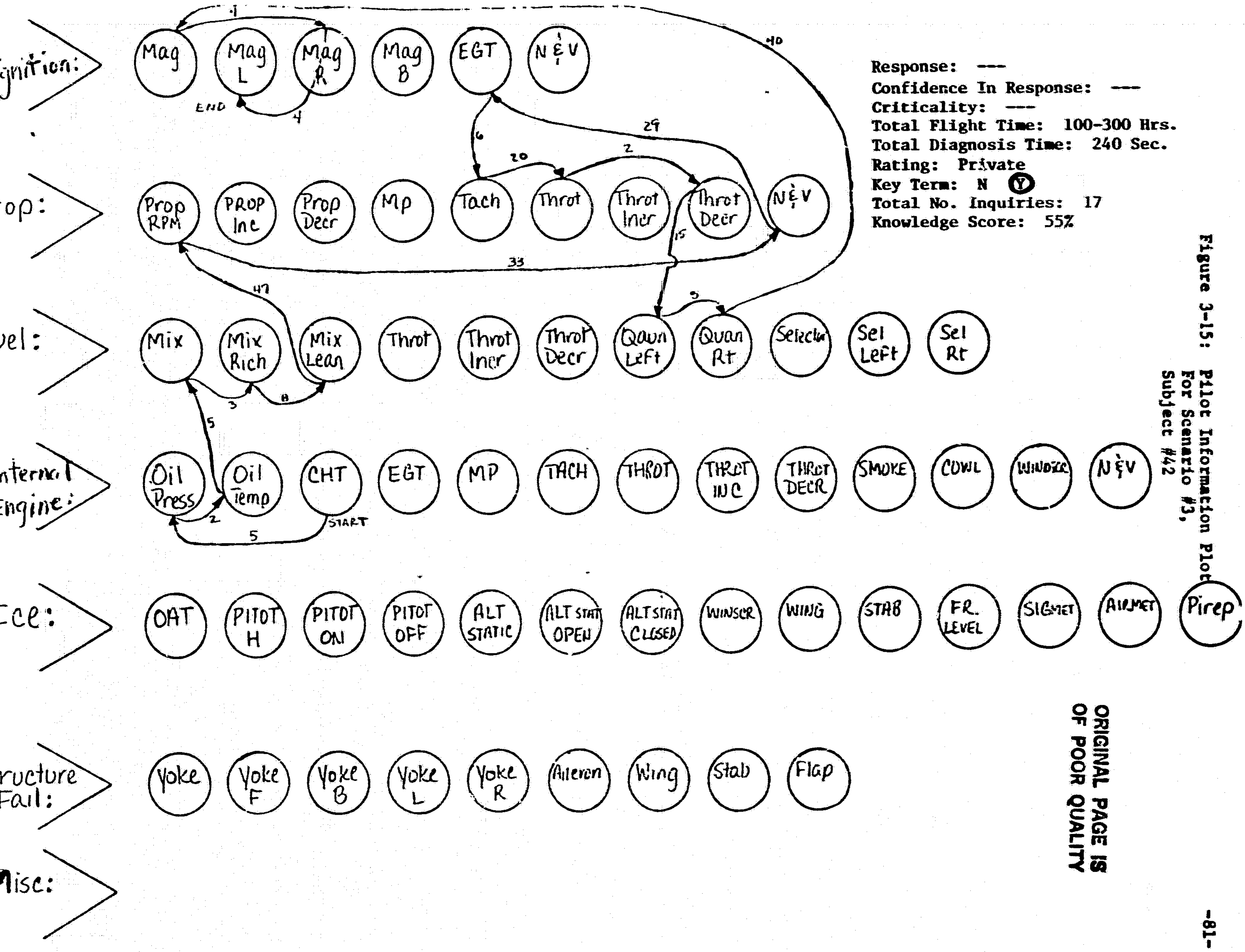
Response: ---
Confidence in Response: ---
Criticality: ---
Total Flight Time: 100-300 Hrs.
Total Diagnosis Time: 241 Sec.
Rating: Private
Key Term: N Y
Total No. Inquiries: 13
Knowledge Score: 55%

Figure 3-15: Pilot Information Plot For Scenario #3, Subject #42



Response: ---
Confidence In Response: ---
Criticality: ---
Total Flight Time: 100-300 Hrs.
Total Diagnosis Time: 240 Sec.
Rating: Private
Key Term: N Y
Total No. Inquiries: 17
Knowledge Score: 55%

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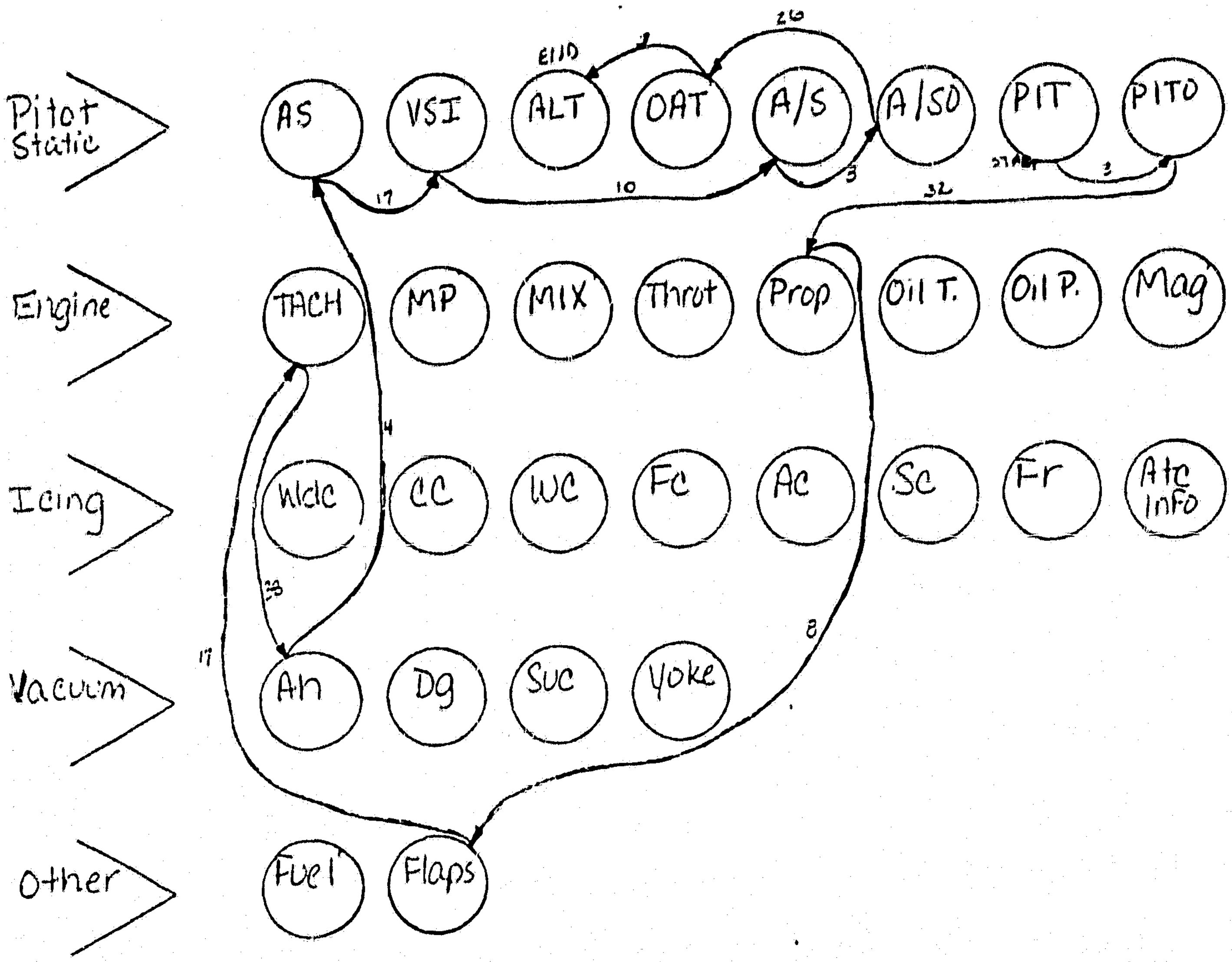
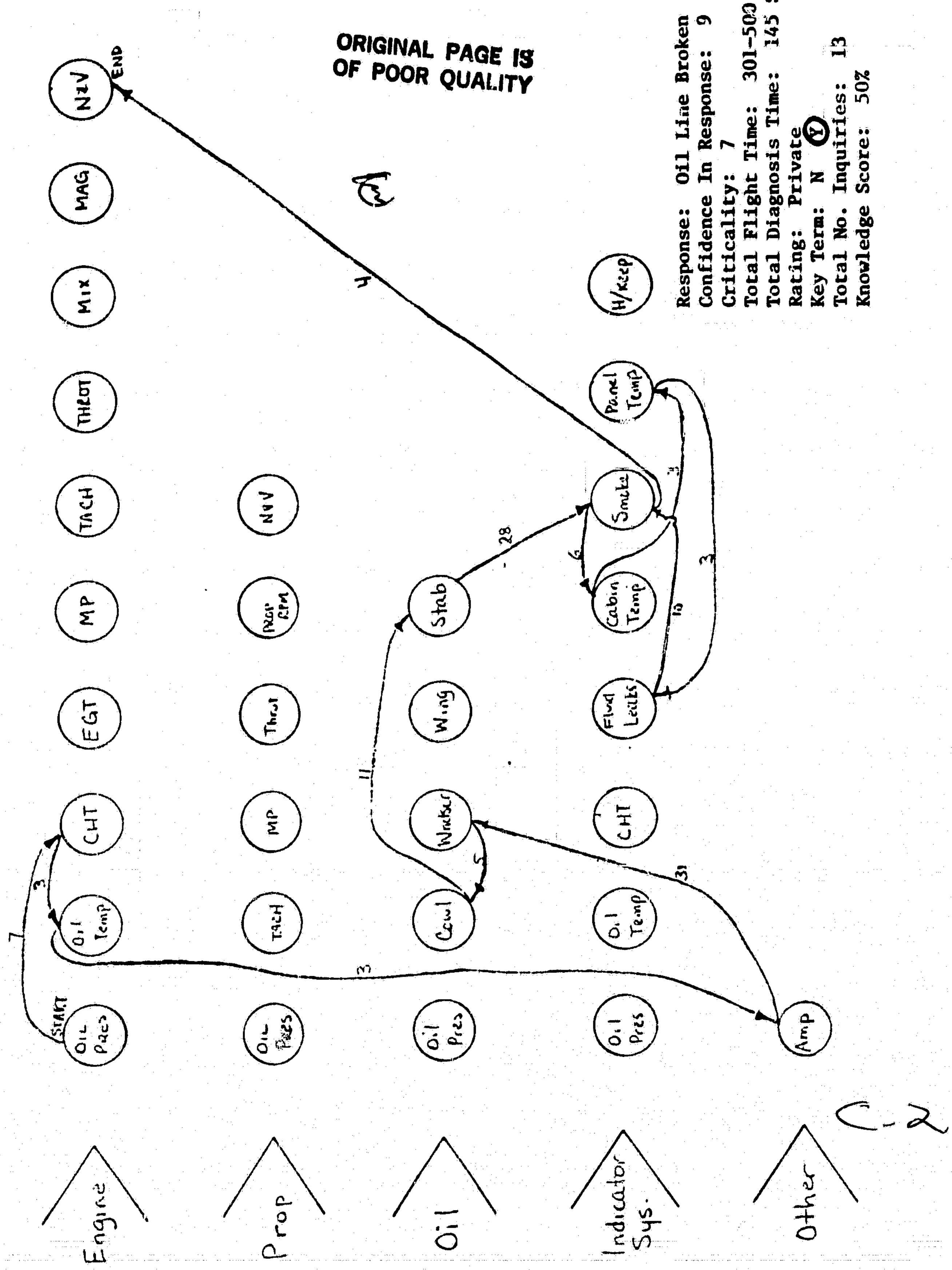


Response: ---
Confidence in Response: ---
Criticality: ---
Total Flight Time: 100-300 Hours
Total Diagnosis Time: 185 Sec.
Rating: Private
Key Term: N Y
Total No. Inquiries: 13
Knowledge Score: 55%

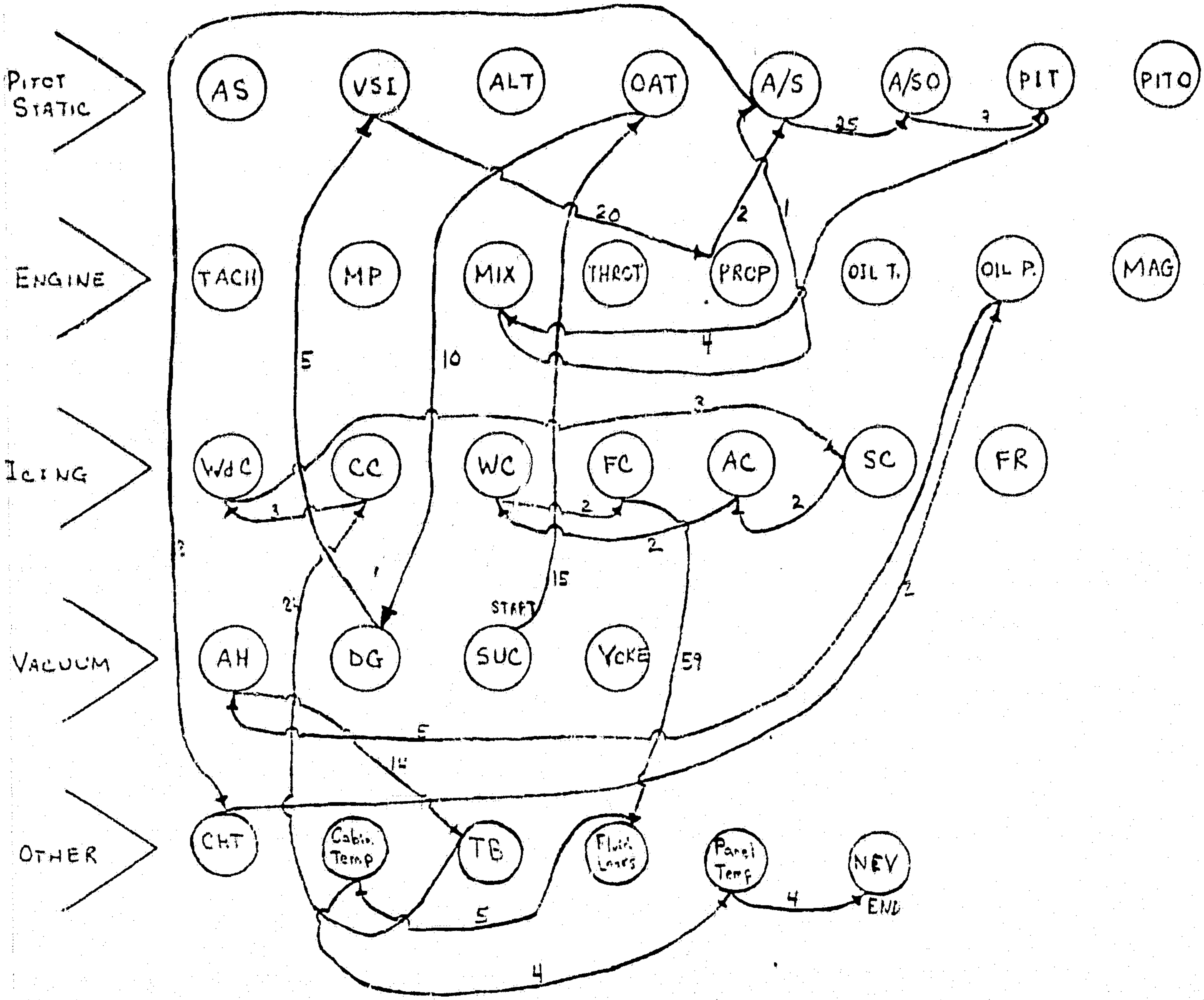
Figure 3-16: Pilot Information Plot For Scenario #4, Subject #42

Figure 3-17: Pilot Information Plot For Scenario #1, Subject #57



Response: Oil Line Broken
Confidence In Response: 9
Criticality: 7
Total Flight Time: 301-500 Hrs.
Total Diagnosis Time: 145 Sec.
Rating: Private
Key Term: N Y
Total No. Inquiries: 13
Knowledge Score: 50%

Figure 3-18: Pilot Information Plot For Scenario #2, Subject #57



Response: Vacuum Pump Failure
Confidence in Response: 5
Criticality: 4
Total Flight Time: 301-500 Hours
Total Diagnosis Time: 241 Sec.
Rating: Private
Key Term: N Y
Total No. Inquiries: 25
Knowledge Score: 50%

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Figure 3-19: Pilot Information Plot For Scenario #3, Subject #57

Response: Piston Broken
Confidence in Response: 6
Criticality: 7
Total Flight Time: 301-500 Hrs.
Total Diagnosis Time: 240 Sec.
Rating: Private
Key Term: N Y
Total No. Inquiries: 36
Knowledge Score: 50%

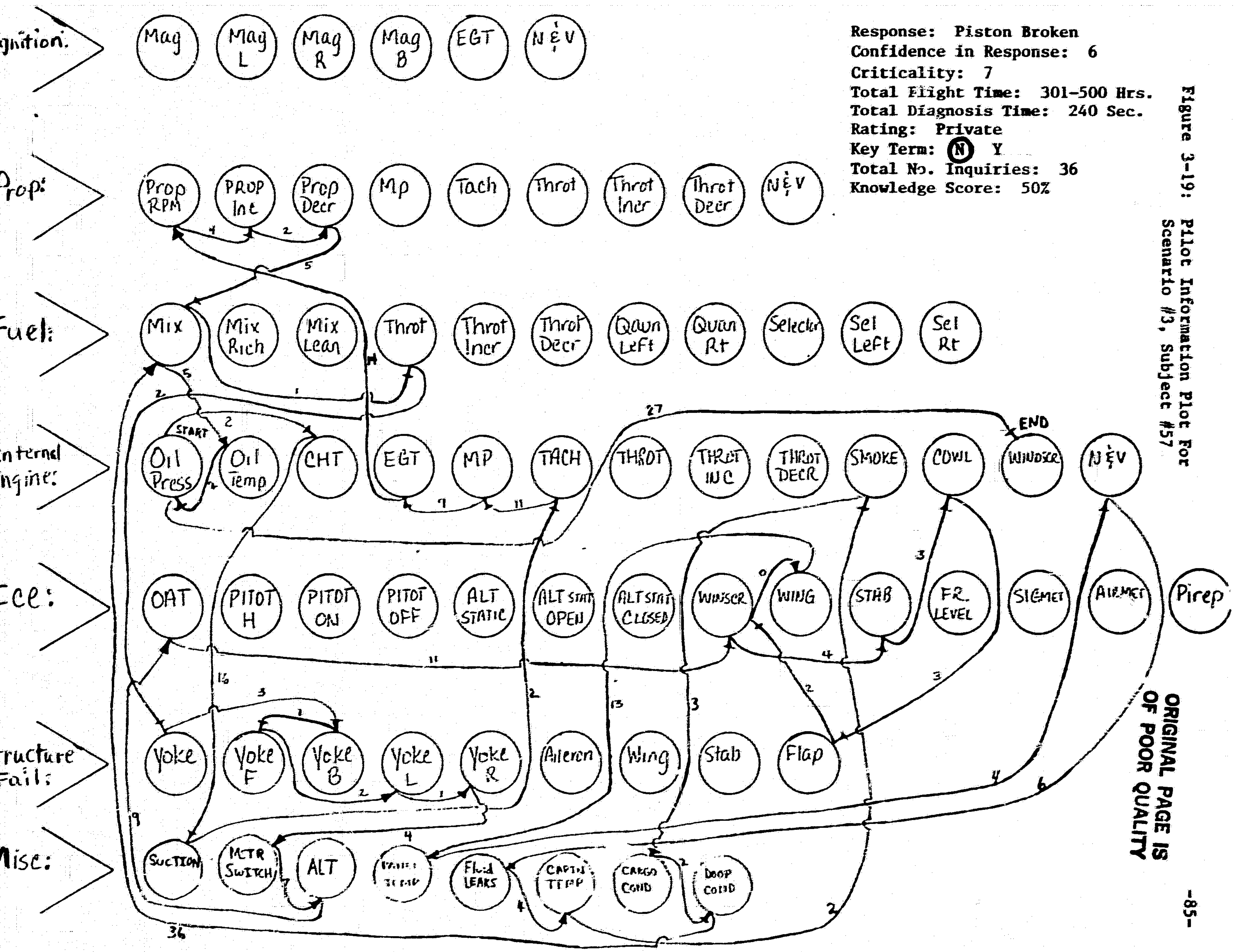

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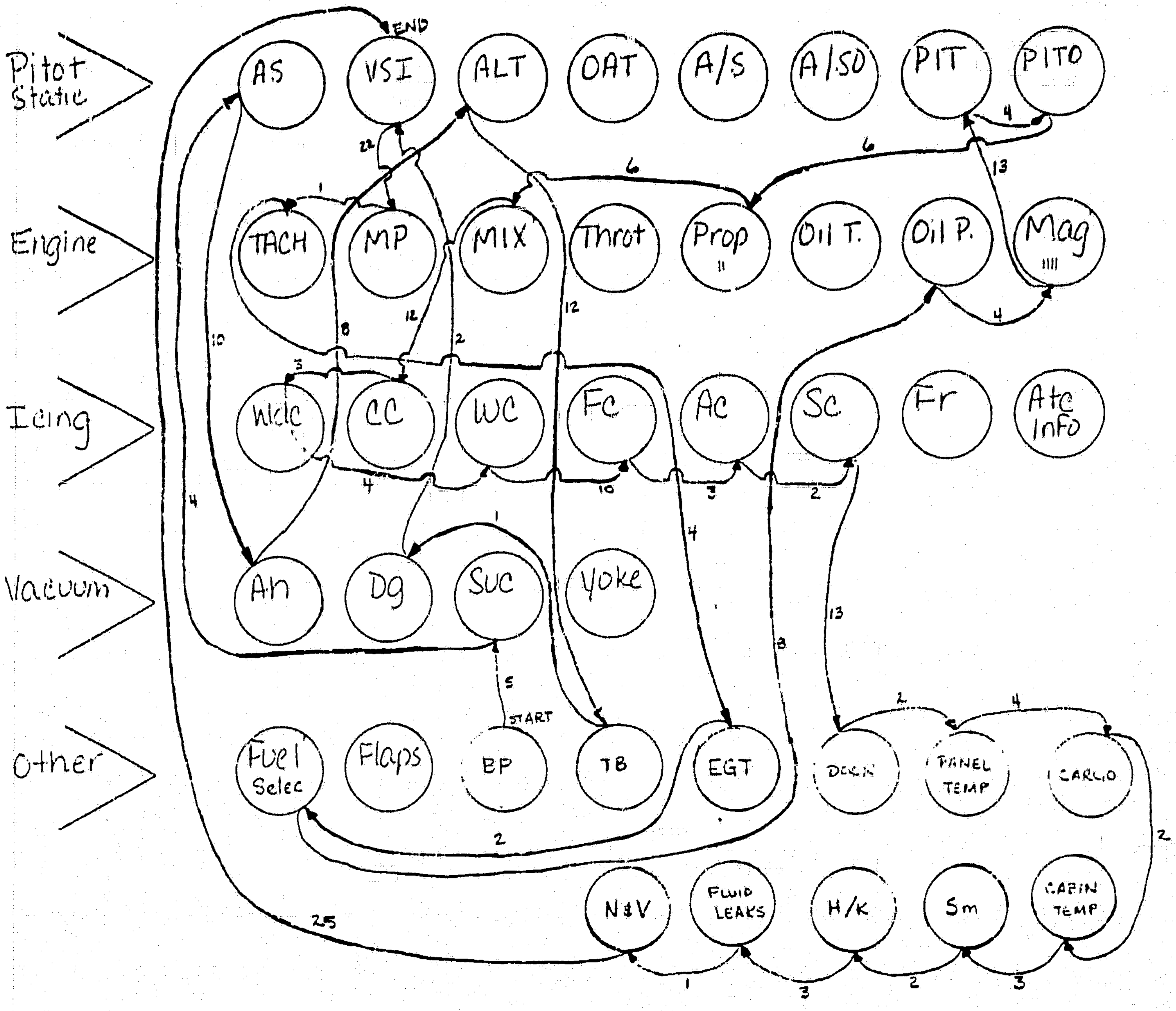
Figure 3-20: Pilot Information Plot For Scenario #4, Subject #57



Response: Structural Ice
Confidence in Response: 7
Criticality: 6
Total Flight Time: 301-500 Hrs.
Total Diagnosis Time: 241 Sec.
Rating: Private
Key Term: N Y
Total No. Inquiries: 40
Knowledge Score: 50%

Schema Analysis

For purposes of comparison, schema diagrams were prepared for two groups of subjects for each diagnostic scenario. The "correct" subjects were those who scored the maximum of five points on a given scenario while the "incorrect" ones scored zero. Each diagram presents the percentage of subjects who included the indicated information in their search versus the median percent order in which that data was requested. (See Figures 3-21 through 3-29).

The schema diagrams for correct and incorrect groups in scenario 1 (Figures 3-22 and 3-23) look remarkably similar. This scenario involves a broken oil pressure gauge line behind the instrument panel. Both groups show a high percentage of interest in oil pressure, oil temperature, and cylinder head temperature (cluster 1) very early in the search process. They also have a similar interest in external evidence of oil on the cowling and windscreen with roughly half of the subjects making such inquiries (cluster 2). General engine health as evidenced by cluster 3 seems to be of less interest. The only distinguishing characteristics appear to be that the correct group looked for fluid leaks, which was the key element, and was concerned with inside physical evidence such as housekeeping and cabin temperature (cluster 4) while the incorrect group ignored this information.

Scenario 2 (Figures 3-24 and 3-25) shows more variation between groups. The only common element shows up in cluster 2 which concerns information related to icing conditions. Roughly half of all subjects seem to believe that this problem, a vacuum pump failure, is ice related. The successful group does check

cluster 1, the gyro instruments and suction gauge, while very few in the unsuccessful group bother to look. Cluster 3 in the correct group represents a small minority of inquiries concerning general aircraft health. The incorrect group does not evidence any strong clustering tendency beyond their concern for ice.

The distinction between correct and incorrect groups in scenario 3 appears to hinge on "cluster fixation" (Figures 3-26 and 3-27). Both groups show a timely concern for general engine health, cluster 2, but only the correct group breaks out of the general health symptoms to check the engine ignition system. This cluster (#1) of course contains the key element since the symptoms are caused by a broken right magneto drive gear.

Scenario 4 involving a frozen static port is somewhat perplexing in view of the great interest in icing symptoms evidenced throughout all the scenarios (Figures 3-28 and 3-29). Although both groups do show strong interest in the potential for ice,(cluster #1) the incorrect group seeks that information early and then abandons that track before reaching the key element. The correct group shows a much broader concern and keeps hammering at the ice question until they uncover the static system problem, albeit rather late in the search process.

Figure 3-21. LIST OF SYMBOLS USED IN SCHEMATA.

Abbreviations

Aileron Cond = AC
Airmets = Air
Alt. Static = A/S
Alt. Static Closed = A/SC
Alt. Static Open = A/SO
Breaker Panel = BP
Cabin Temp = CT
Cargo = Car
Ceiling = Ceil
Cowling Condition = CC
Cloud Tops = CLT
Cycle Head Temp = CHT
Flap Condition = FC
Flaps = F
Fluid Leaks = FL
Freezing Level = Fr
Fuel Selec = FS
Fuel Selec. Left = FSL
Fuel Selec. Right = FSR
Ground Speed = GrS
Left Fuel Quant. = LFQ
Housekeeping = H/K
Mag Both = Mag B
Mag Left = Mag L
Mag Right = Mag R
Master Switch = MS
Master Switch On = MSO
Master Switch Off = MSOF
Mix = Mx
Mix Enrich = MxE
Mix Lean = MxL
Nav. Aid Stat. = NAV
Noise & Vibration = NV
Oil Pressure = OP
Oil Temp = OT
Panel Temp = PT
Pireps = Pir
Pitot Heat = PH
Pitot Heat Off = PHOF
Pitot Heat On = PHO
Prop RPM = PR
Prop PDM Decr = PRD
Prop RPM Inc = PRI
Right Fuel Qty = RFQ
Sigmets = Sig
Smoke = Sm
Stabilizer Cond = SC
Suction = Suc
Throttle = Thr
Throttle Dec = ThrD
Throttle Incr = ThrI
Winds Aloft = WA
Windscreen Cond = WdC
Wind Cord = WC
Visibility = Vis

Subjects: 42, 43, 46, 47, 51, 52, 53, 54, 55, 56, 57, 59, 60, 61, 64, 67, 68, 80

Frequency (%) vs. Order (Median)

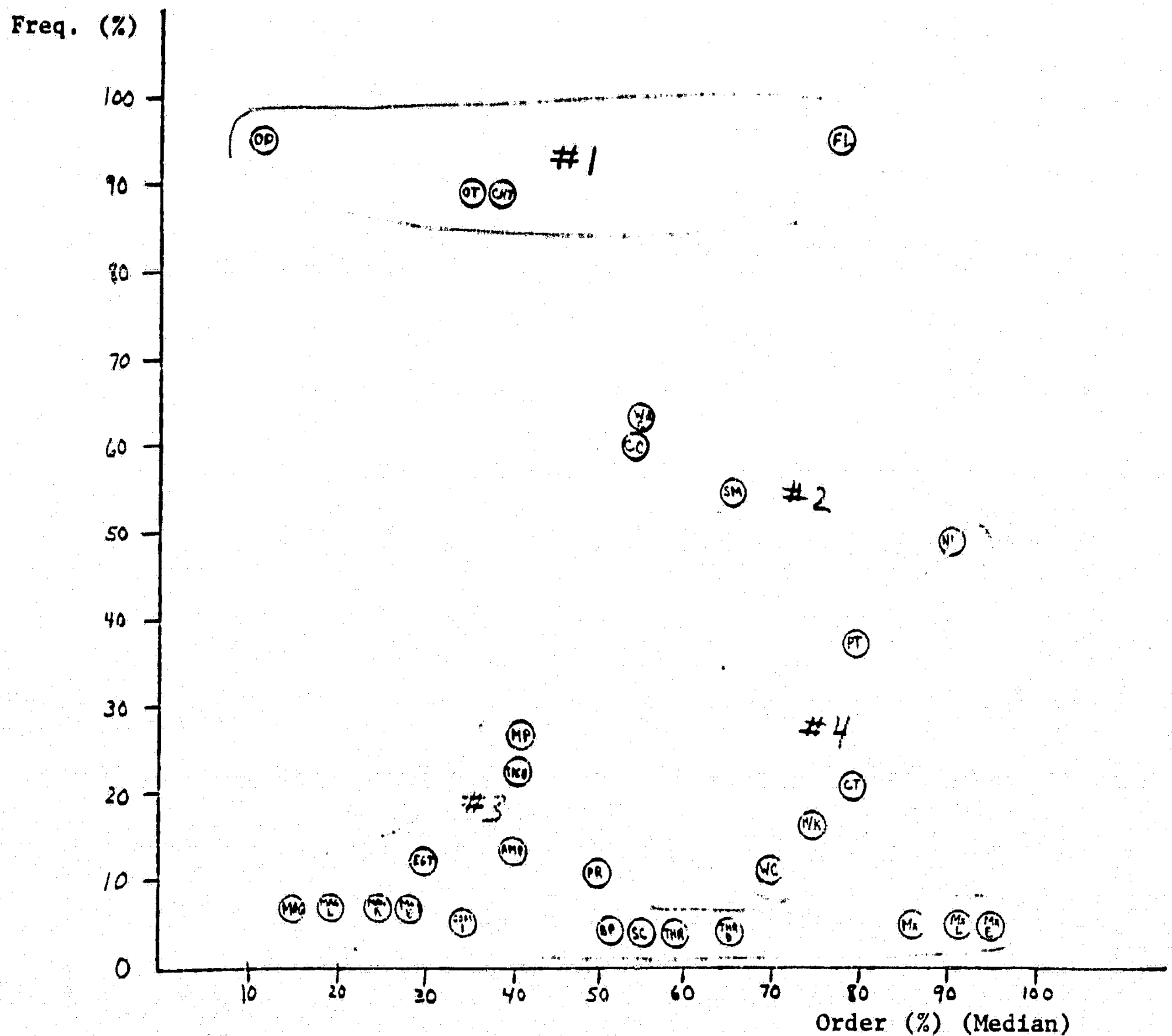


Figure 3-22: Schema For Subjects In Scenario #1 With Correct Diagnosis
(See Figure 3-21 for the list of symbols used in schemata)

Subjects: 45, 48, 49, 50, 58, 65

Frequency (%) vs. Order (Median)

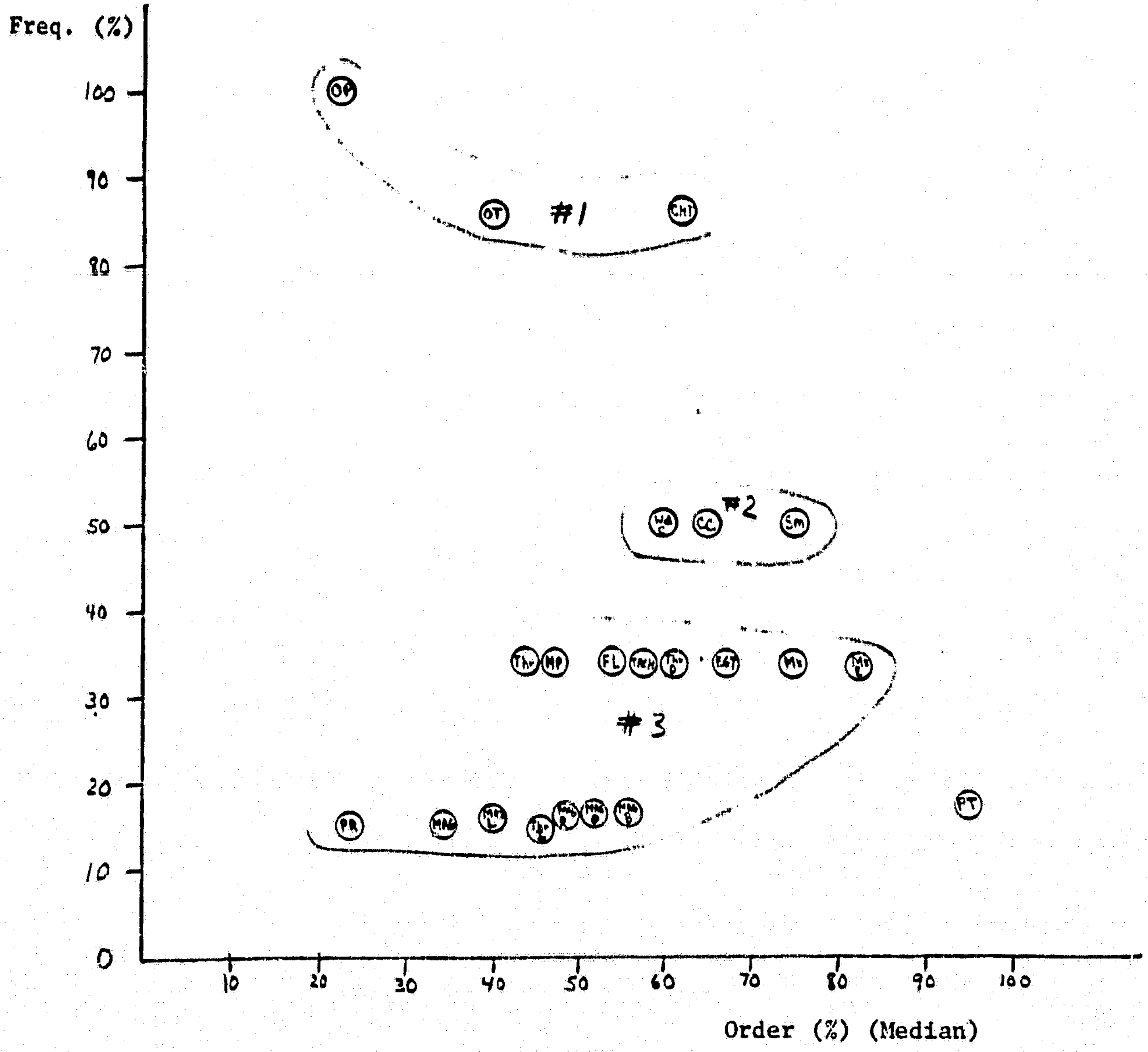


Figure 3-23: Schema For Subjects In
Scenario #1 With Incorrect Diagnosis

Subjects: 45, 49, 50, 51, 57, 63, 71, 72, 77, 80

Frequency (%) vs. Order (Median)

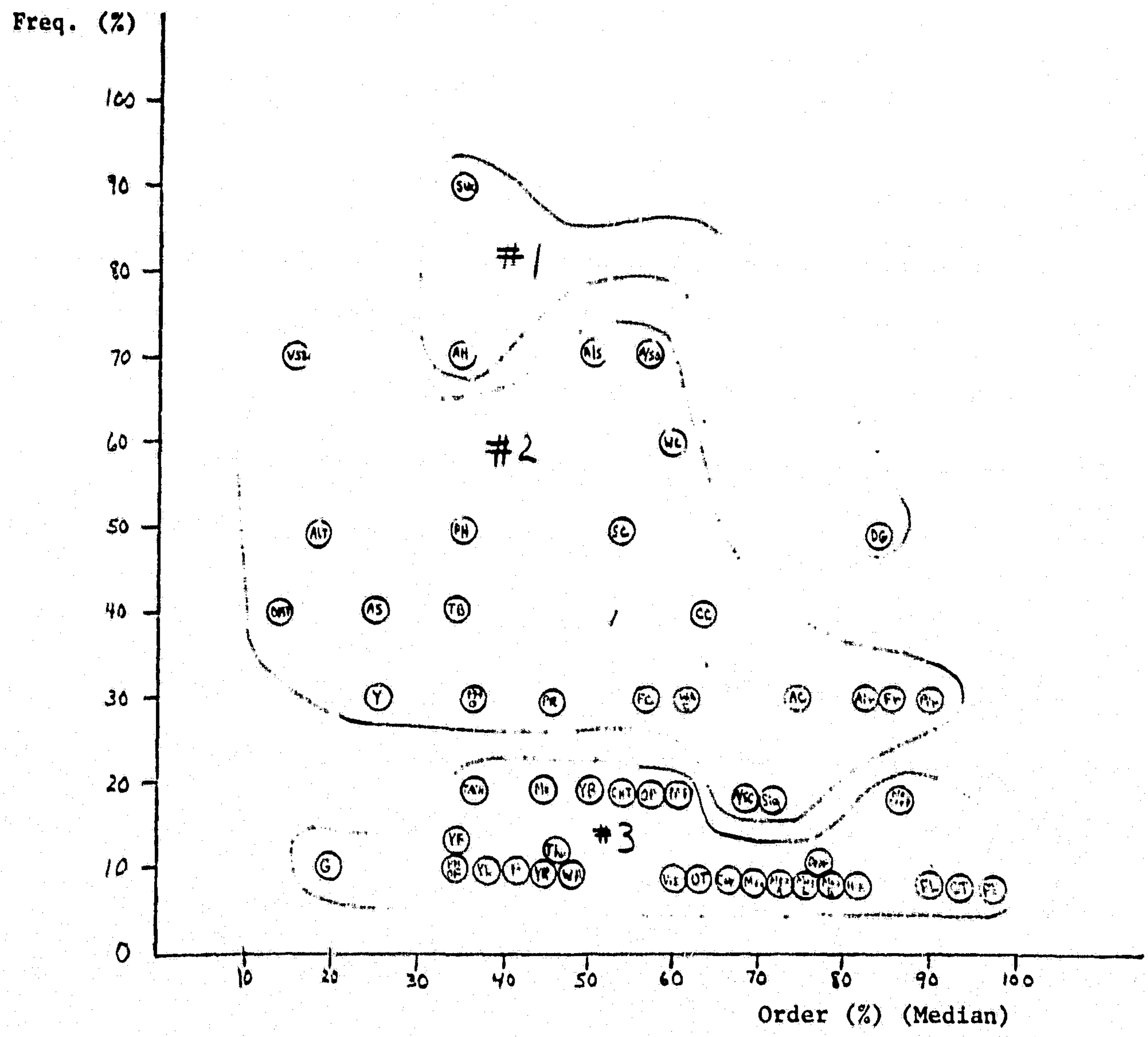


Figure 3-24: Schema For Subjects In
Scenario #2 With Correct Diagnosis

Subjects: 42, 44, 46, 48, 52, 54, 55, 56, 58, 59, 60, 62, 64, 65, 66
66, 68, 70, 73, 75, 76, 78, 79, 81, 82, 83, 84

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Frequency (%) vs. Order (Median)

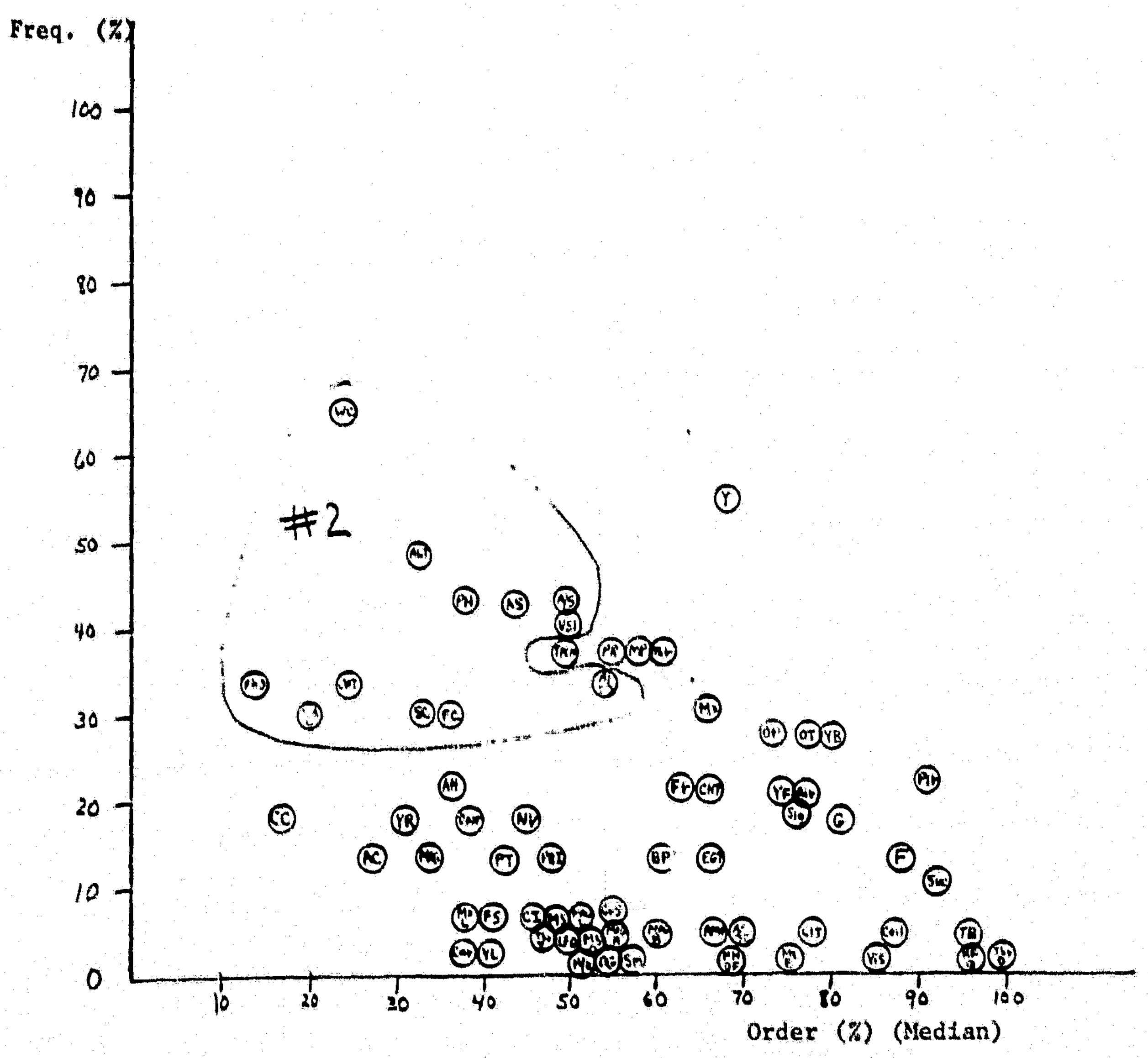

Figure 3-25: Schema For Subjects In
Scenario #2 With Incorrect Diagnosis

Subjects: 42, 43, 46, 49, 50, 51, 52, 53, 54, 56, 58, 59, 60, 63, 65, 71, 73, 75, 78, 80, 82, 83

Frequency (%) vs. Order (Median)

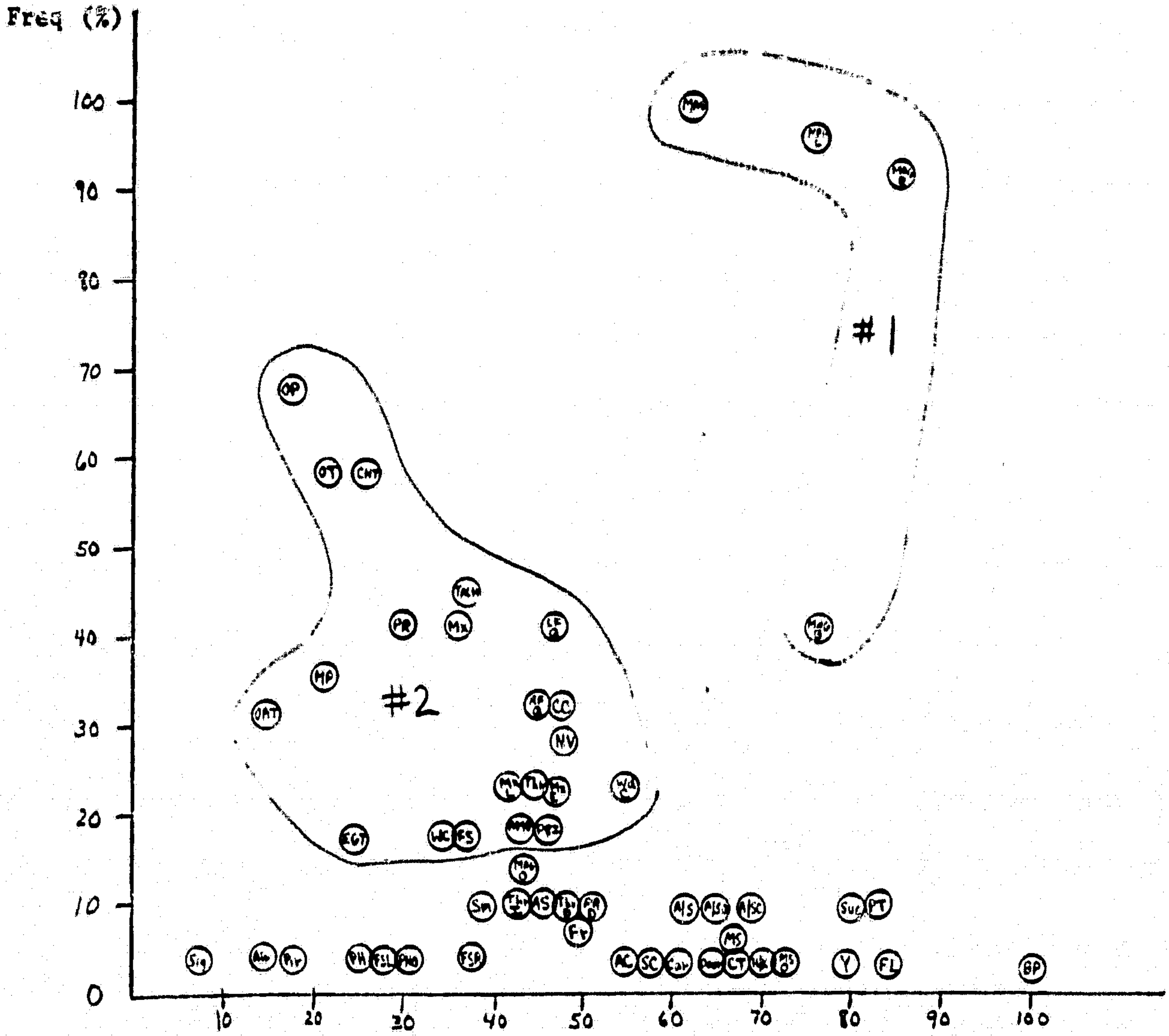

Figure 3-26: Schema For Subjects In
Scenario #3 With Correct Diagnosis

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Subjects: 45, 47, 48, 55, 56, 61, 62, 66, 68, 72

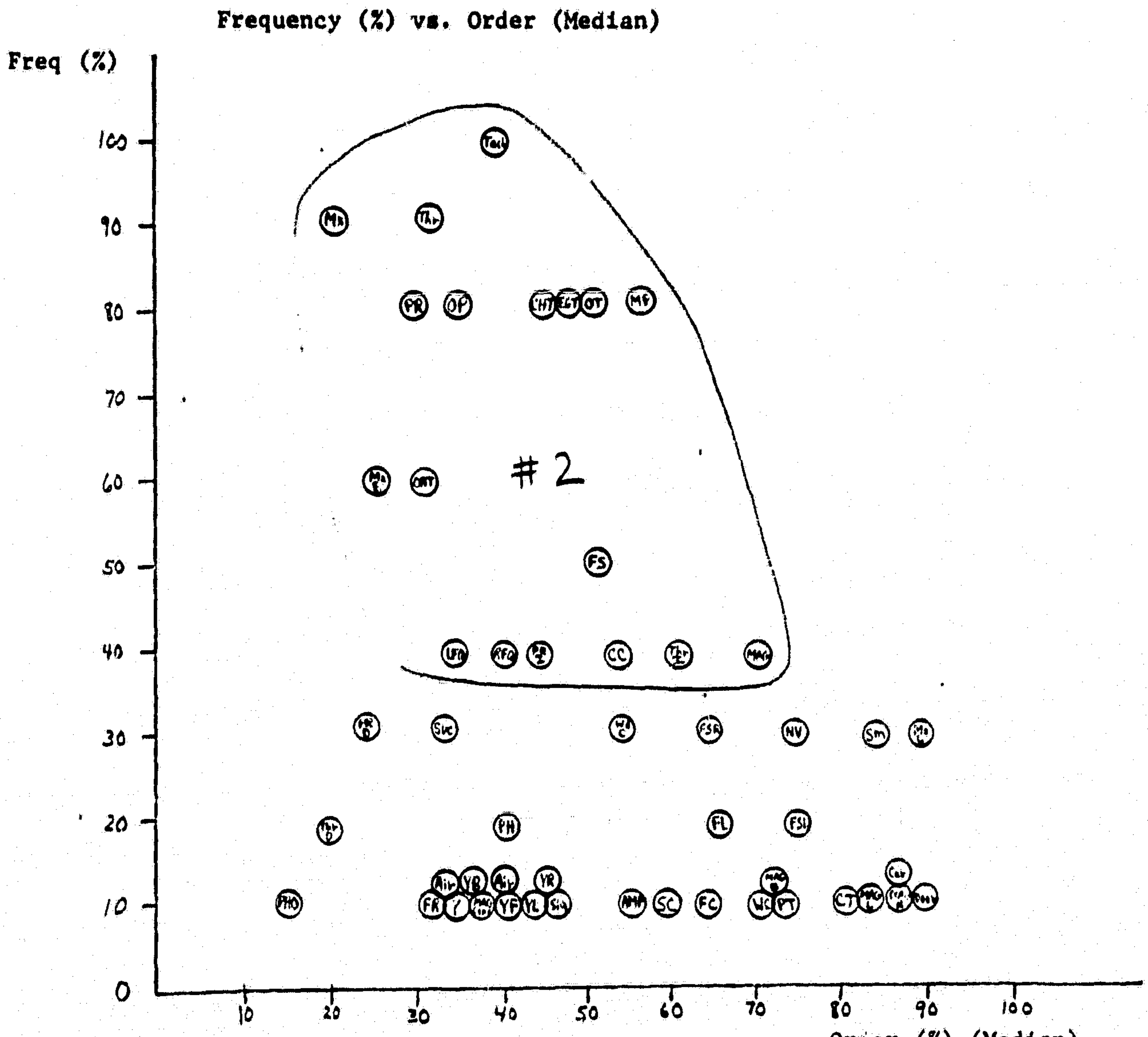

Figure 3-27: Schema For Subjects In Scenario #3 With Incorrect Diagnosis

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Subjects: 42, 43, 46, 48, 50, 51, 53, 55, 58, 61, 64, 65, 70, 75, 78

Frequency (%) vs. Order (Median)

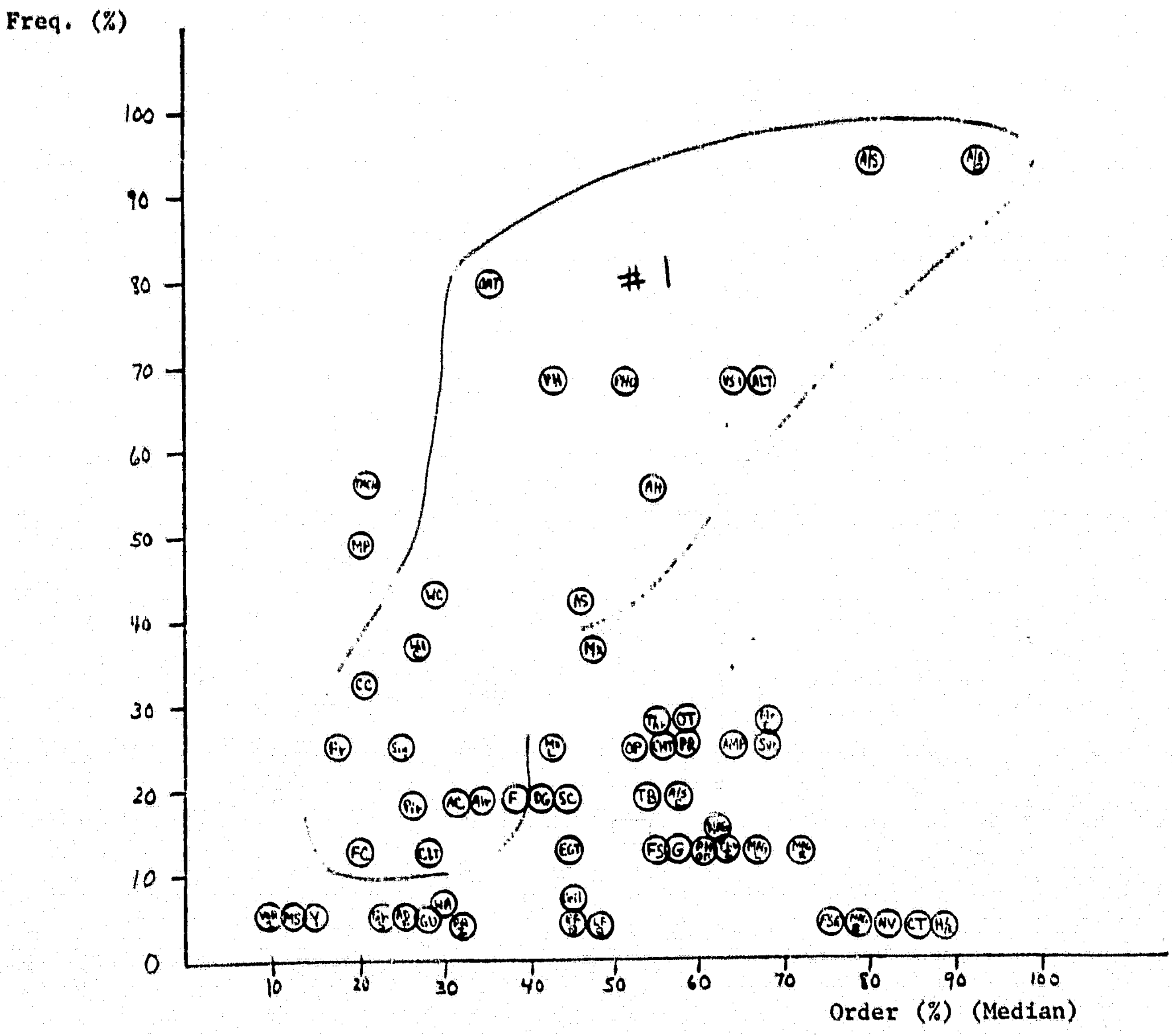

Figure 3-28: Schema For Subjects In Scenario #4 With Correct Diagnosis

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Subjects: 45, 47, 49, 54, 71

Frequency (%) vs. Order (Median)

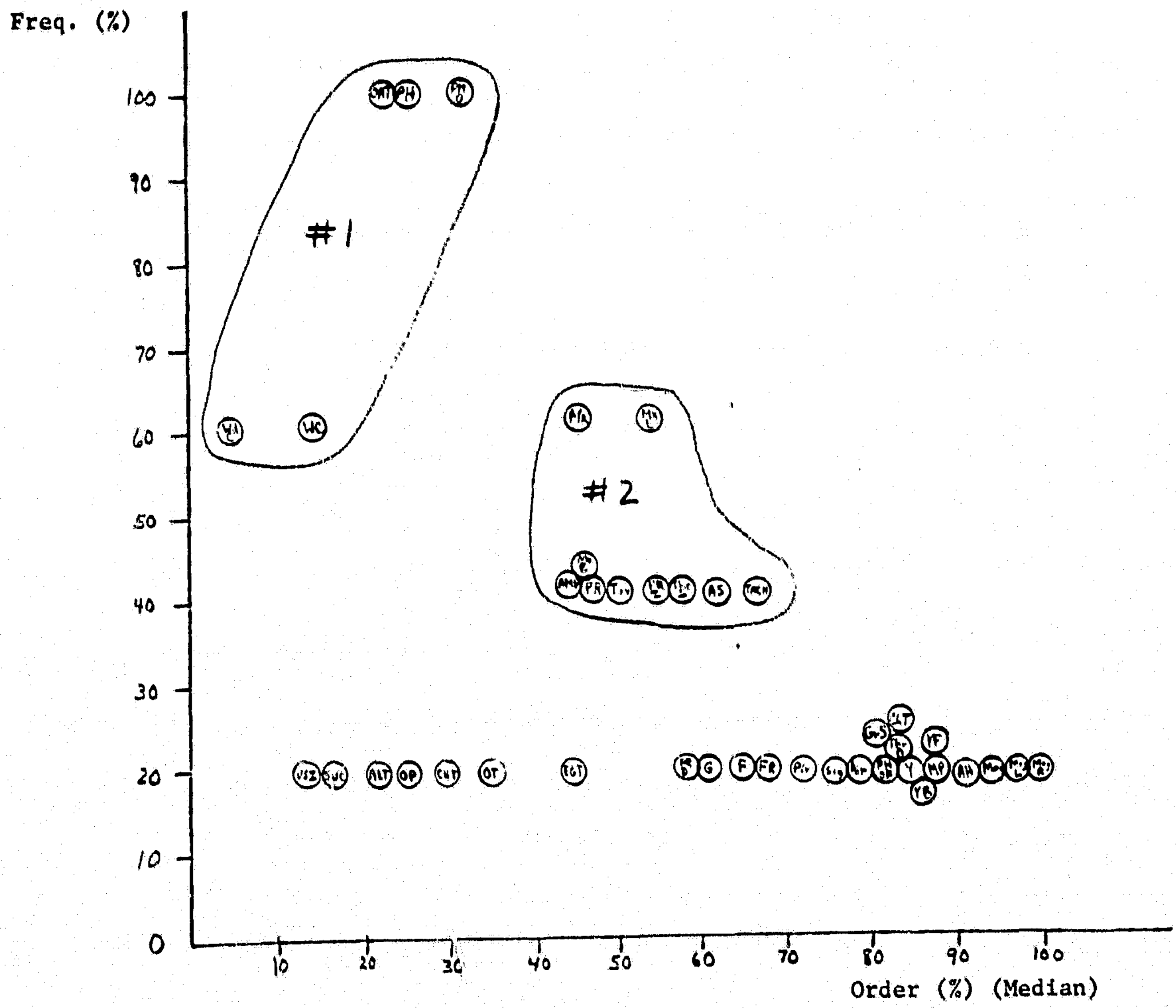

Figure 3-29: Schema For Subjects In Scenario #4 With Incorrect Diagnosis

G. Destination Diversion Performance

The destination diversion problem involved selecting an airport from among sixteen candidates distributed around the geographic area in which the alternator failure occurred. Six items of information could be requested for each airport during the two minute search period. The information available included: (1) bearing and distance, (2) ceiling, (3) visibility, (4) approach aids, (5) ATC services, and (6) terrain. The location of the airports relative to the point of failure is depicted in Figure 3-30. The problem is somewhat complicated by the presence of a strong southwest wind which was noted in the presentation of the scenario.

The characteristics of each of the sixteen airports are noted in Table 3-10. The characteristics were chosen to represent extremes in desirability, e.g. mountainous versus level terrain, ILS versus NDB approaches, 500 foot versus 1000 foot ceilings, etc.

The number of information requests among the thirty subjects who completed this part of the experiment is summarized in Table 3-11. The items of information most often requested were ceiling and visibility which seems consistent with the order of information in weather reports. The low number of requests for terrain information (rank 5 of the 6 classes) is somewhat surprising. One wonders about the wisdom of selecting an airport on the basis of electronic aids which may face imminent failure without knowing the potential hostility of surrounding terrain. The airports receiving the most information requests were airports 3 and 5. The high frequency of requests for those airports may be due simply to their perceived proximity to the point of failure as determined from the simplified

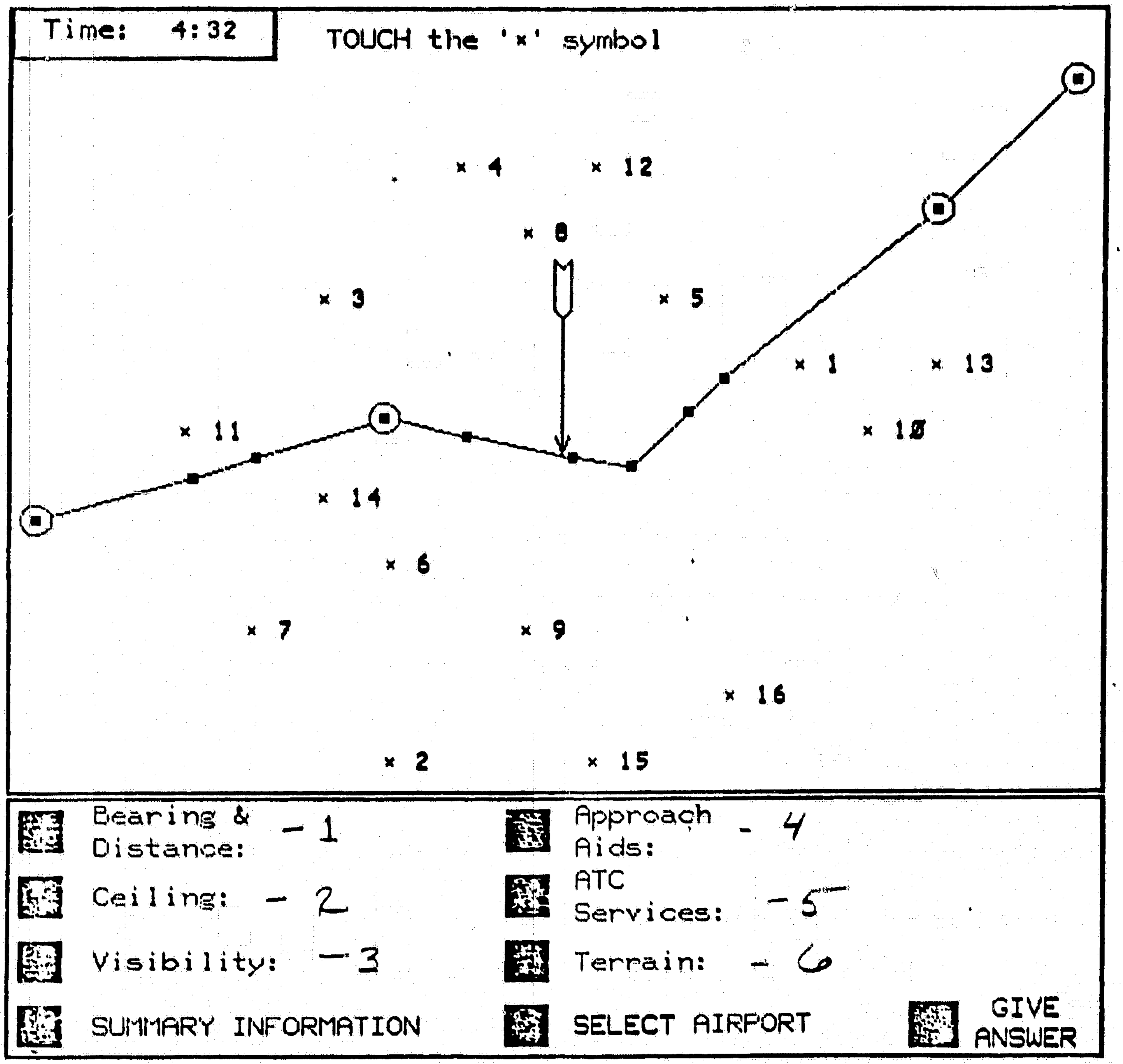

Figure 3-30. SIMPLIFIED ENROUTE CHART FOR DIVISION DECISION

AIRPORT	BEARING & DISTANCE		CEILING	VISIBILITY	APPROACH AIDS	ATC SERVICES	TERRAIN
1	080°	60	500	2	ILS	TWR	LEVEL
2	230°	50	700	1	ILS	NONE	HILLY
3	330°	60	1000	3	VOR	TWR(R)	HILLY
4	350°	65	500	1	NDB	NONE	HILLY
5	060°	35	700	2	NDB	NONE	MOUNT
6	270°	40	700	2	NDB	NONE	MOUNT
7	270°	50	500	2	ILS	NONE	MOUNT
8	010°	50	700	2	NDB	NONE	MOUNT
9	200°	25	500	1	NDB	FSS	HILLY
10	100°	55	500	1	ILS	TWR(R)	LEVEL
11	290°	65	700	2	ILS	NONE	MOUNT
12	030°	60	1000	3	ILS	NONE	MOUNT
13	090°	70	1000	2	ILS	TWR(R)	LEVEL
14	290°	35	700	2	VOR	TWR	MOUNT
15	190°	40	700	2	ILS	TWR	HILLY
16	150°	40	500	1	VOR	TWR(R)	LEVEL

Table 3-10: AIRPORT CHARACTERISTICS

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Airport \ Info	Bearing & Distance 1	Ceiling 2	Visibility 3	Approach Aids 4	ATC Services 5	Terrain 6	Total	Frequency of Selection
1	9	15	15	12	10	11	72	8
2	0	0	0	0	0	0	0	0
3	16	18	18	14	13	11	90	10
4	0	4	3	1	0	1	9	0
5	11	21	20	16	13	11	92	1
6	12	16	15	14	8	7	72	2
7	2	2	2	2	0	0	8	1
8	11	16	14	11	9	9	70	0
9	11	18	17	9	5	5	65	0
10	3	6	6	4	2	5	26	0
11	3	6	5	3	1	1	19	0
12	2	4	4	3	4	4	21	2
13	0	1	1	1	0	1	4	0
14	11	20	17	12	9	11	80	3
15	0	0	0	0	1	0	1	0
16	2	4	4	3	2	3	18	1
Total	93	151	141	105	77	80	647	28/30*

* Two subjects out of 30 did not select an airport

Table 3-11 Destination Diversion Information Requests and Decisions

enroute chart. However, had the subjects considered wind effects, airport 3 should have received much less attention than some others.

The most popular choices for destination diversion airports were airports 1 and 3. On the surface these two represent distinctly different choices. Both are equidistant from the point of failure. However, airport 1 is in level terrain, downwind and has an ILS approach, while airport 3 is in hilly terrain, upwind with a non-precision VOR approach. Ceiling and visibility are 500 and 1 for airport 1 versus 1000 and 3 for airport 3. Several t-tests were run to test the effect of flying experience, knowledge test scores, diagnostic scenario performance and airport information type requests on the choice of one of these two airports. None of these proved to be statistically significant. Whatever influenced the choice of airport 1 versus airport 3, it is not immediately apparent from the subject characteristics examined.

Figures 3-31 through 3-33 present relative frequency information derived from the table of information requests. Here it is possible to see at a glance the dominance of airports 1 and 3 and information on ceiling and visibility. It is interesting to note that the information frequency profile for those two airports is virtually identical. Profiles for other airports exhibit decidedly different patterns.

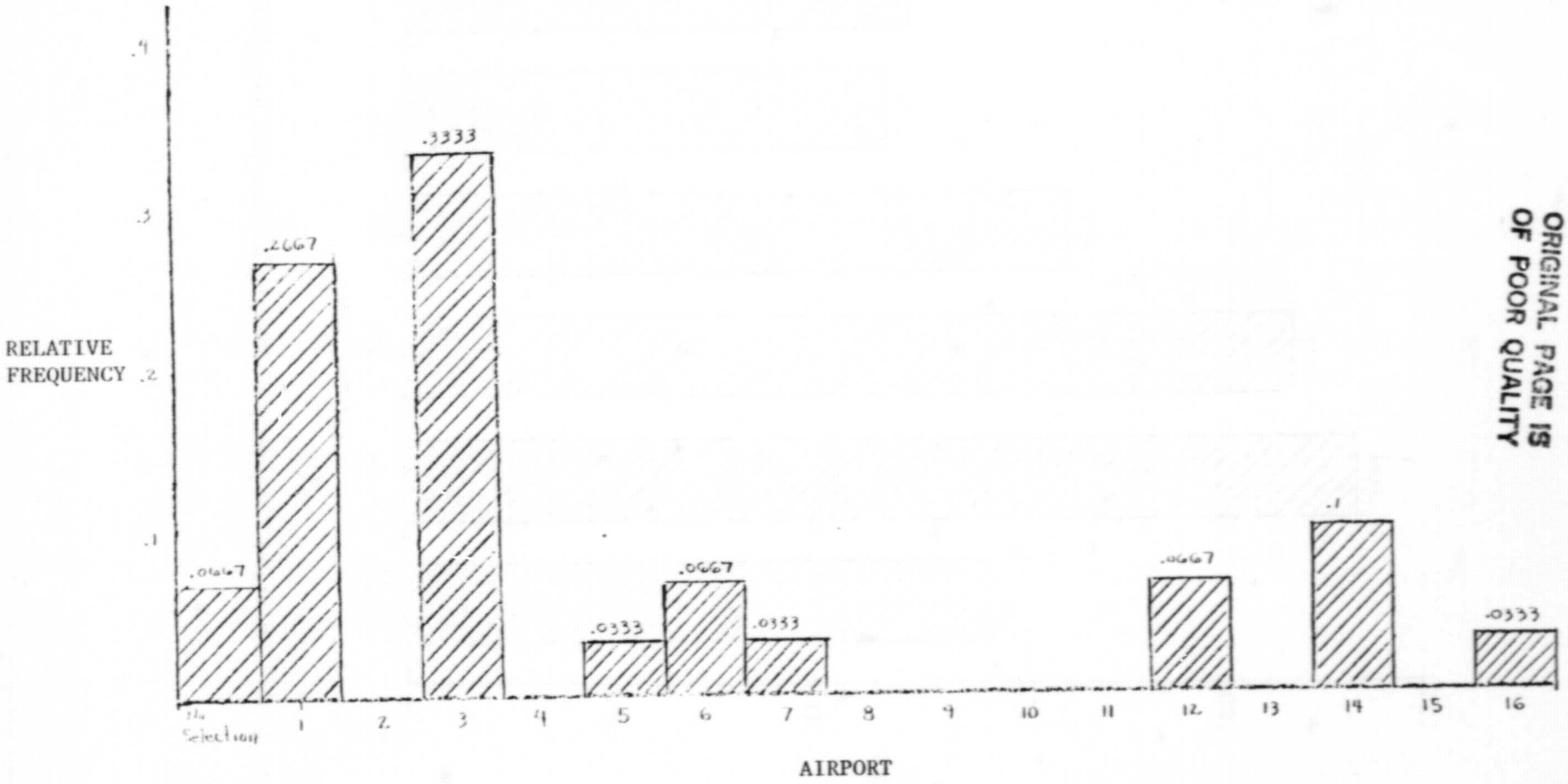


Figure 3-31: Relative Frequency of Selection of Each Airport

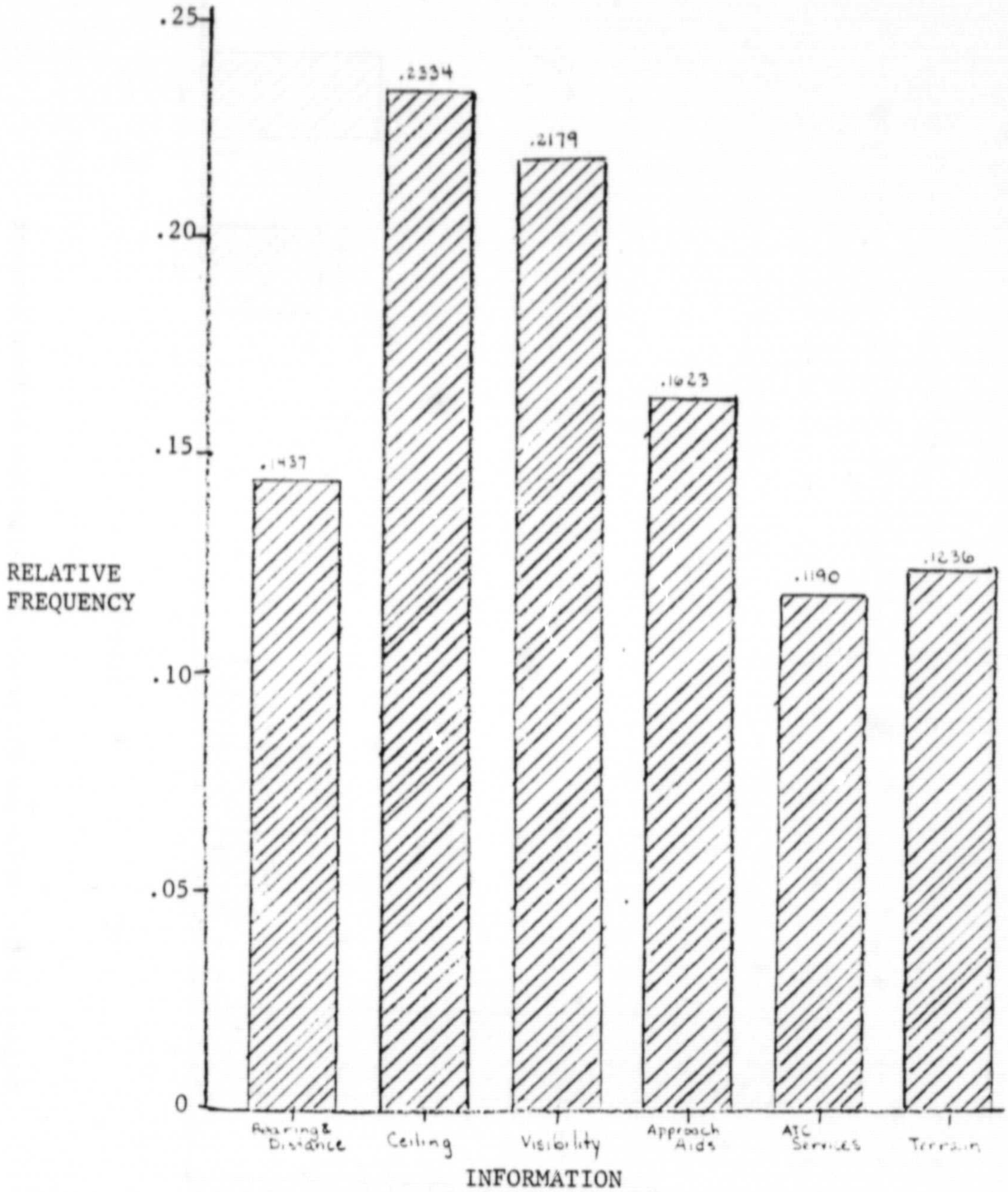
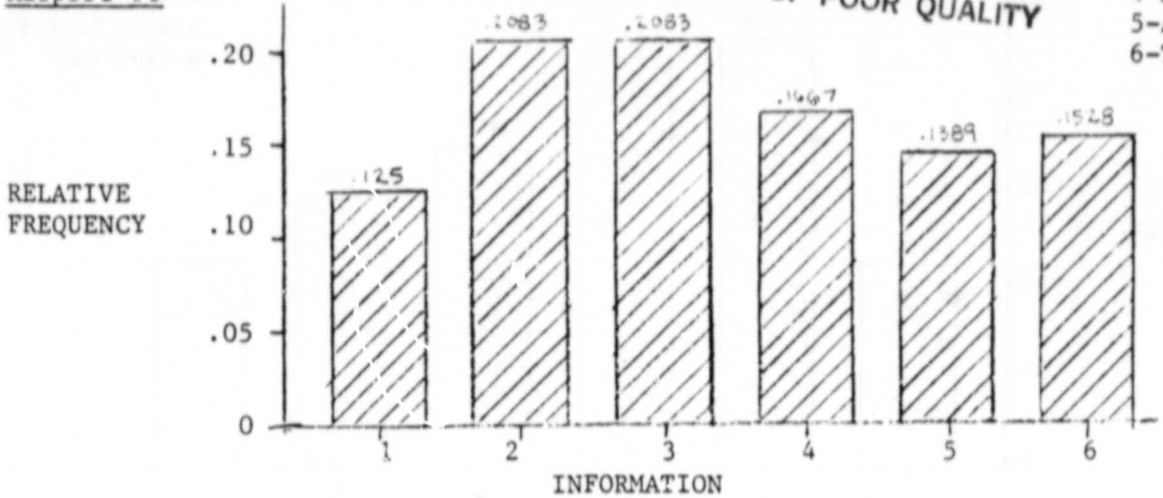


Figure 3-32: Relative Frequency of Total Information Requests

Figure 3-33: Relative Frequency Of Information Requests By Airport

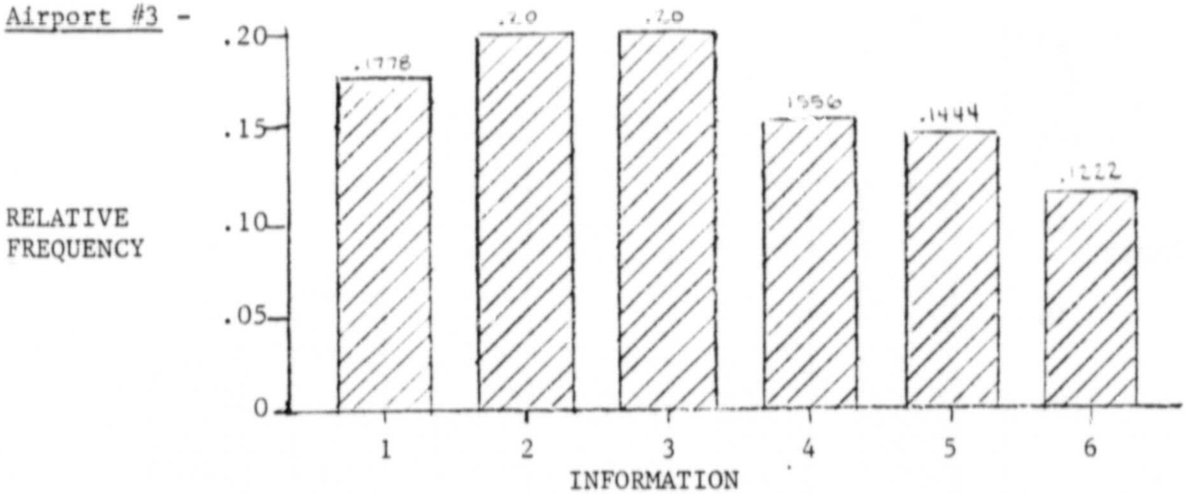
Key: 1-Bearing & Distance
2-Ceiling
3-Visibility
4-Approach Aids
5-ATC Facilities
6-Terrain

Airport #1

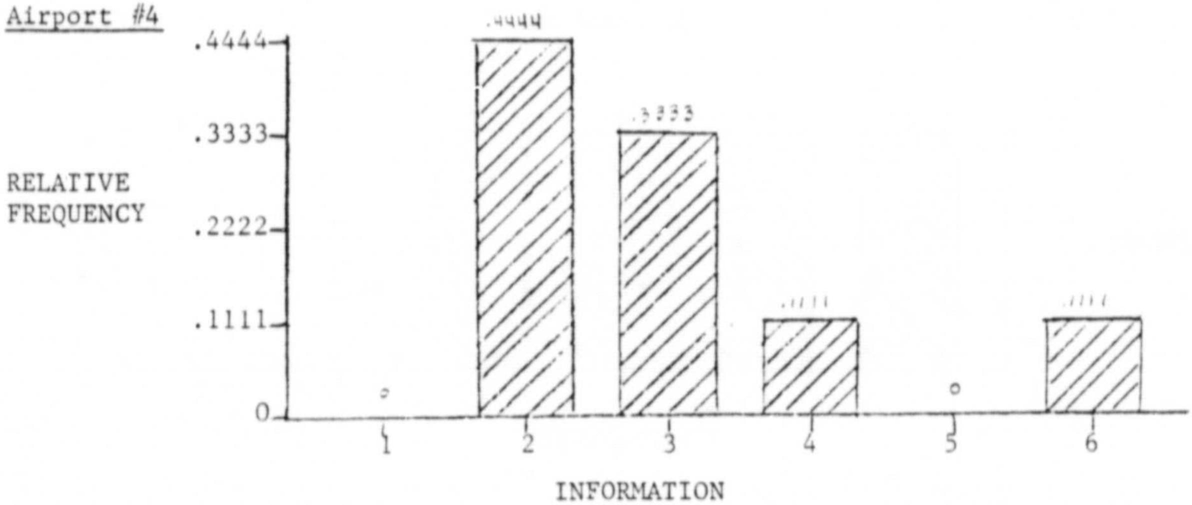


Airport #2 - No Information Requested

Airport #3 -

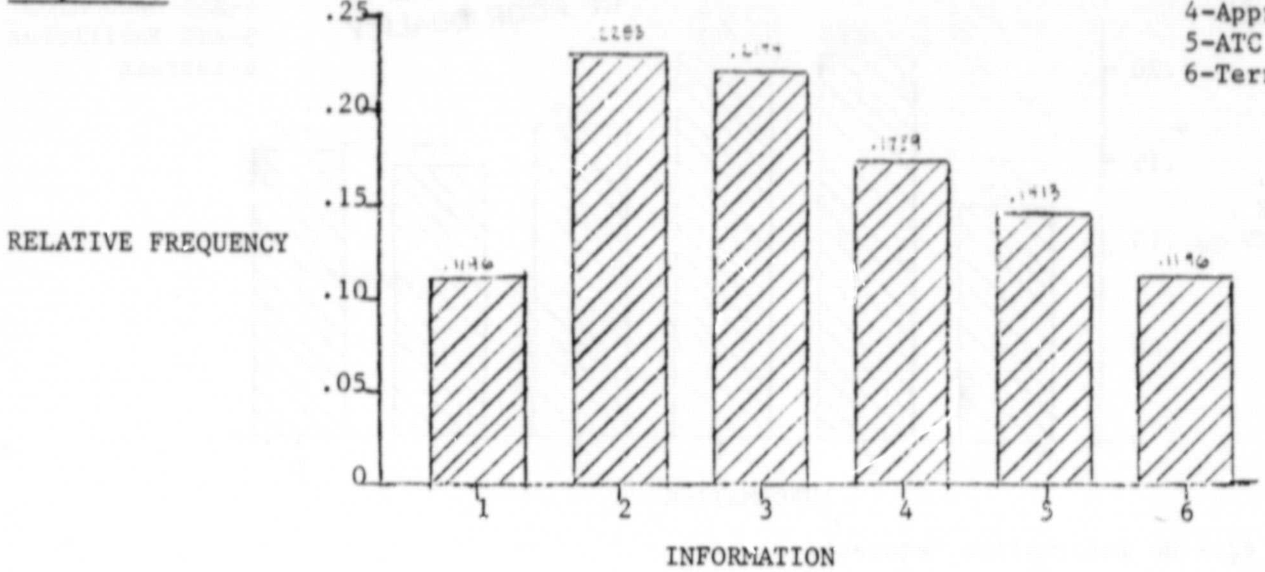


Airport #4

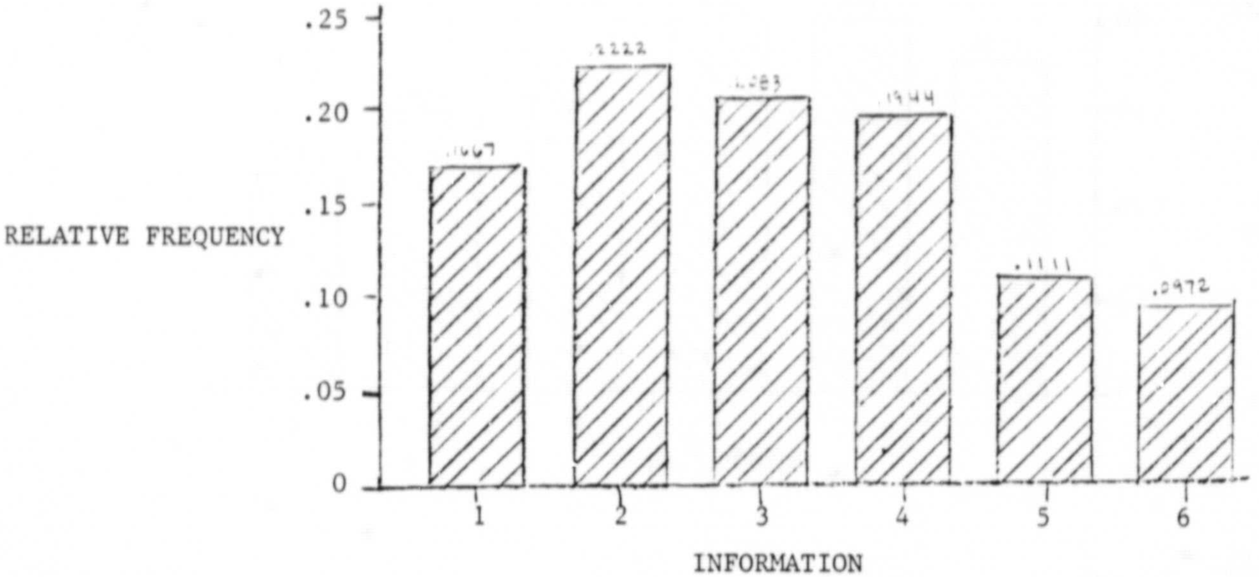


Key: 1-Bearing & Distance
2-Ceiling
3-Visibility
4-Approach Aids
5-ATC Facilities
6-Terrain

Airport #5



Airport #6



Airport #7

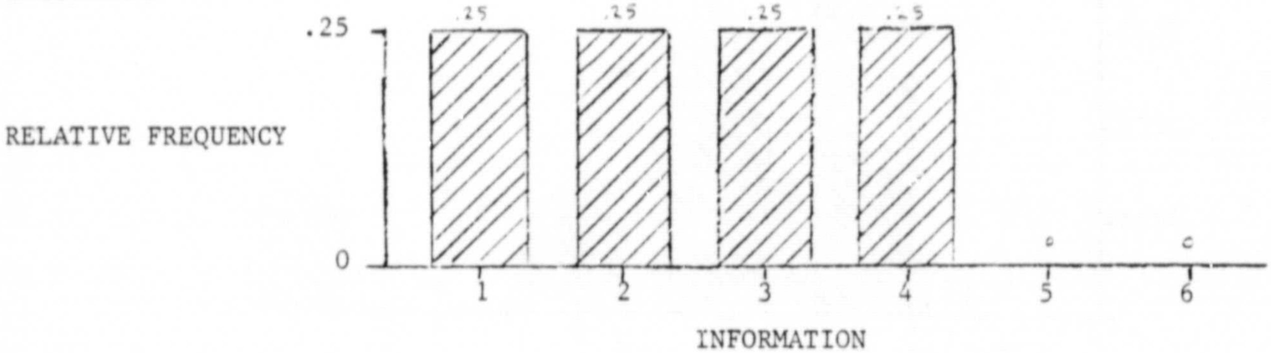
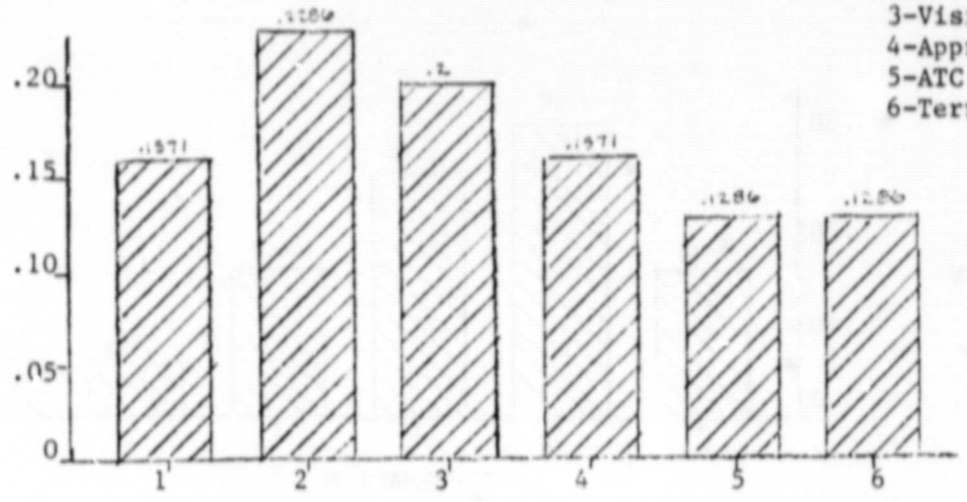


Figure 3-33 (continued)

Key: 1-Bearing & Distance
2-Ceiling
3-Visibility
4-Approach Aids
5-ATC Faciltiies
6-Terrain

Airport #8

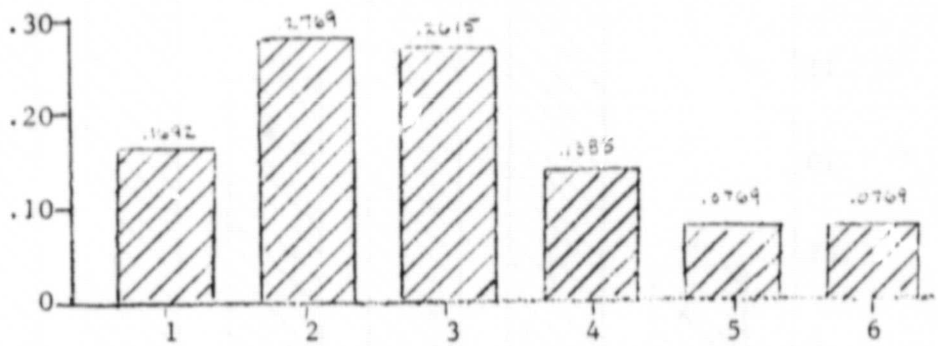
RELATIVE FREQUENCY



INFORMATION

Airport #9

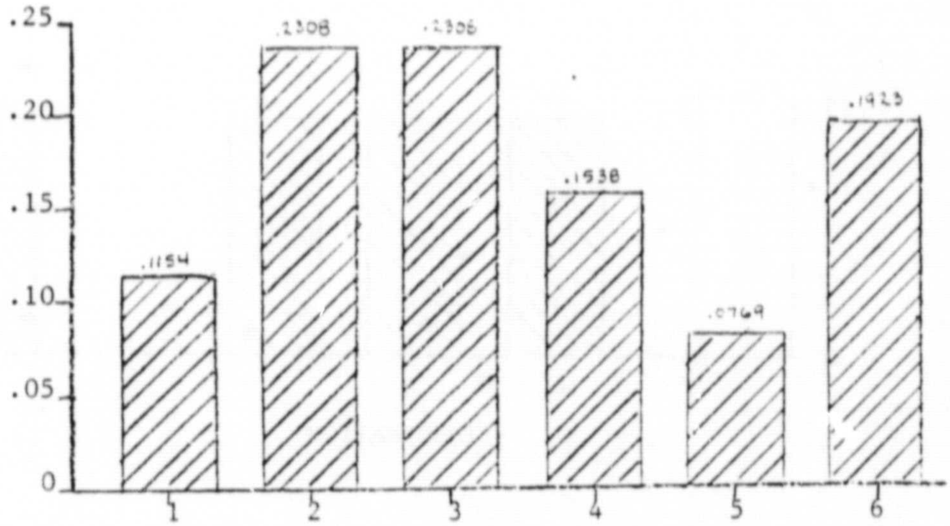
RELATIVE FREQUENCY



INFORMATION

Airport #10

RELATIVE FREQUENCY



INFORMATION

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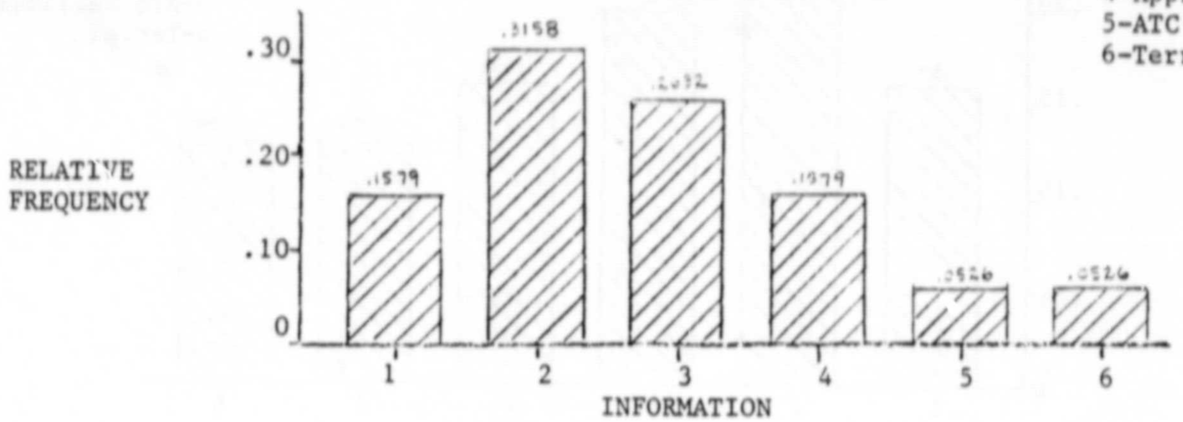
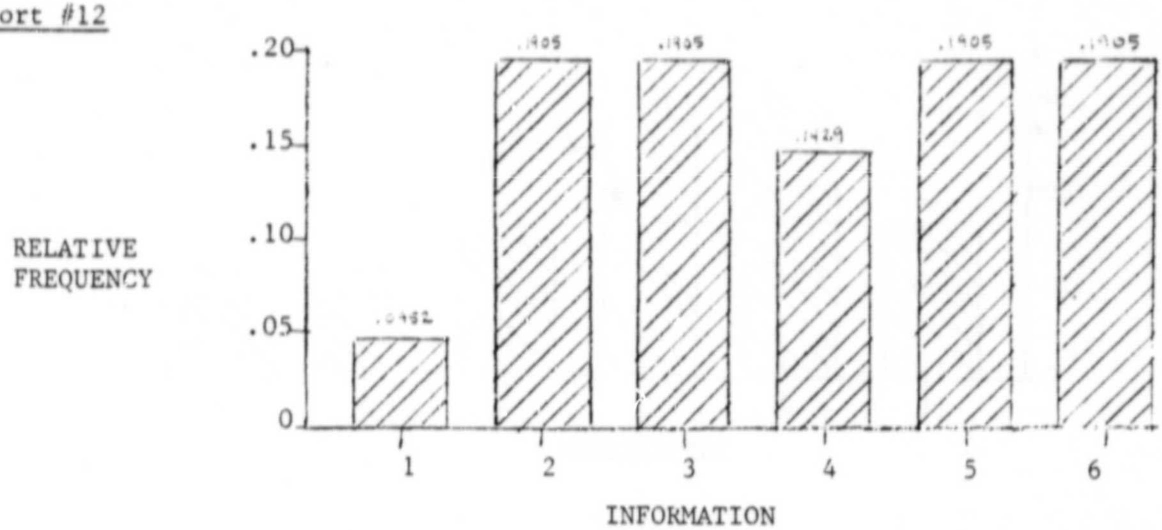
Figure 3-33 (continued

Key: 1-Bearing & Distance
2-Ceiling
3-Visibility
4-Approach Aids
5-ATC Facilities
6-Terrain

Airport #11



Airport #12



Airport #13

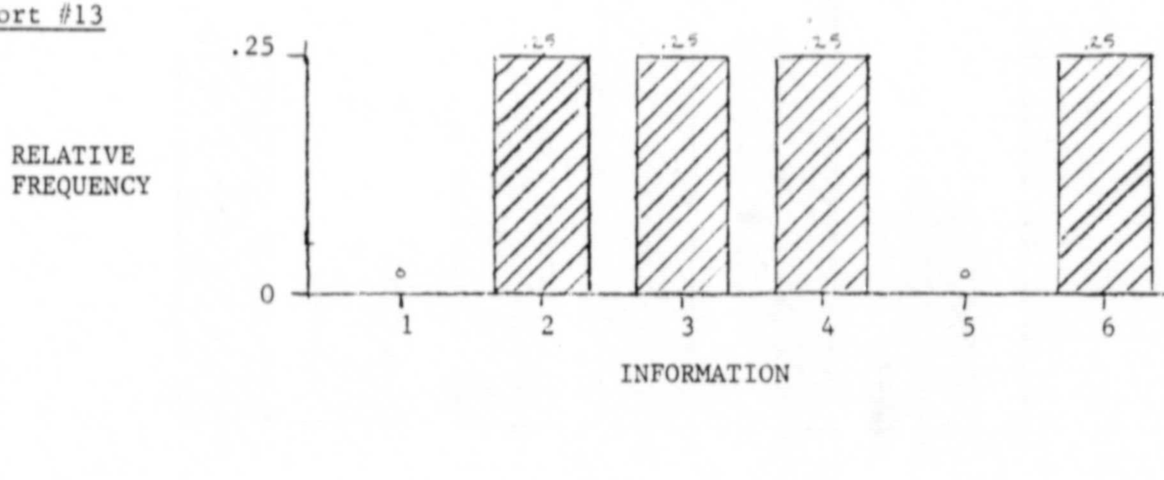
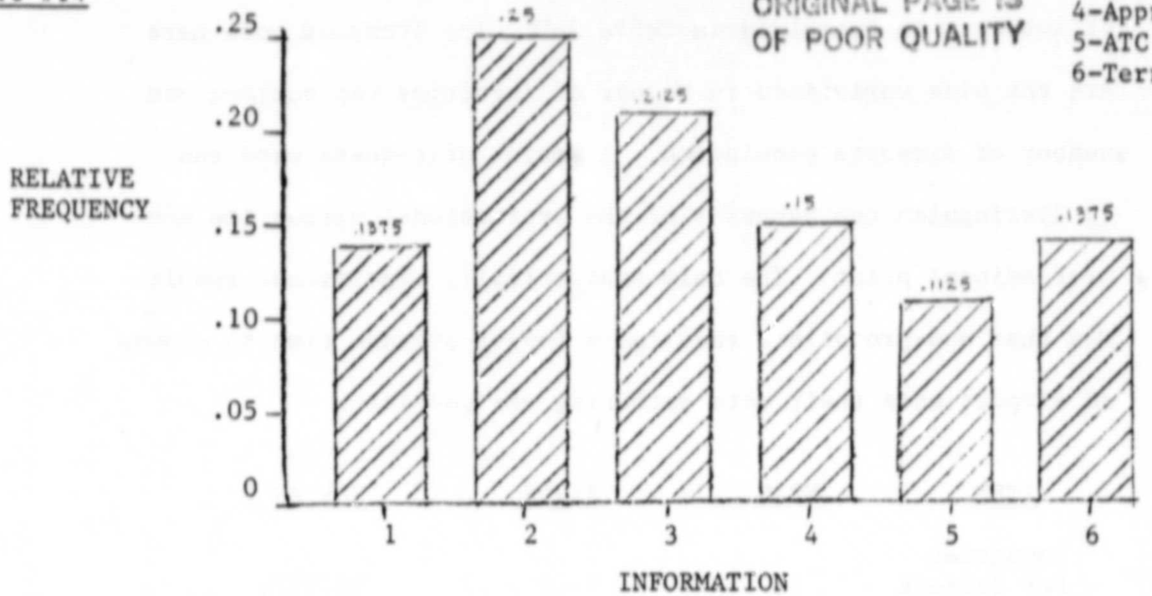


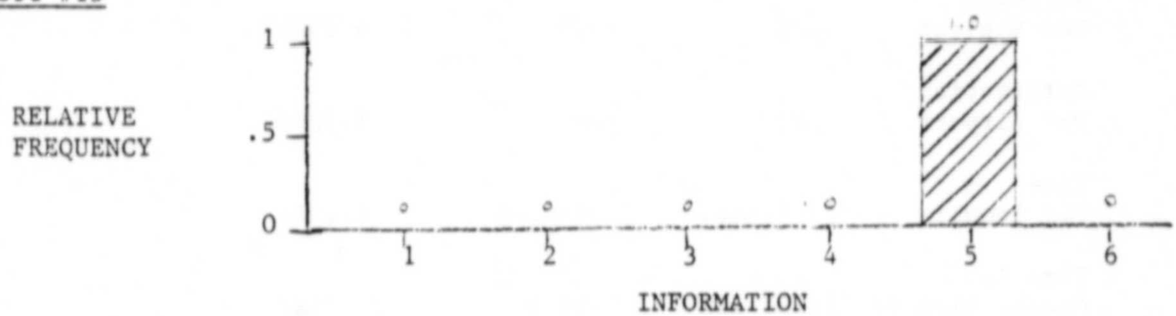
Figure 3-33 (continued)

Key: 1-Bearing & Distance
2-Ceiling
3-Visibility
4-Approach Aids
5-ATC Facilities
6-Terrain

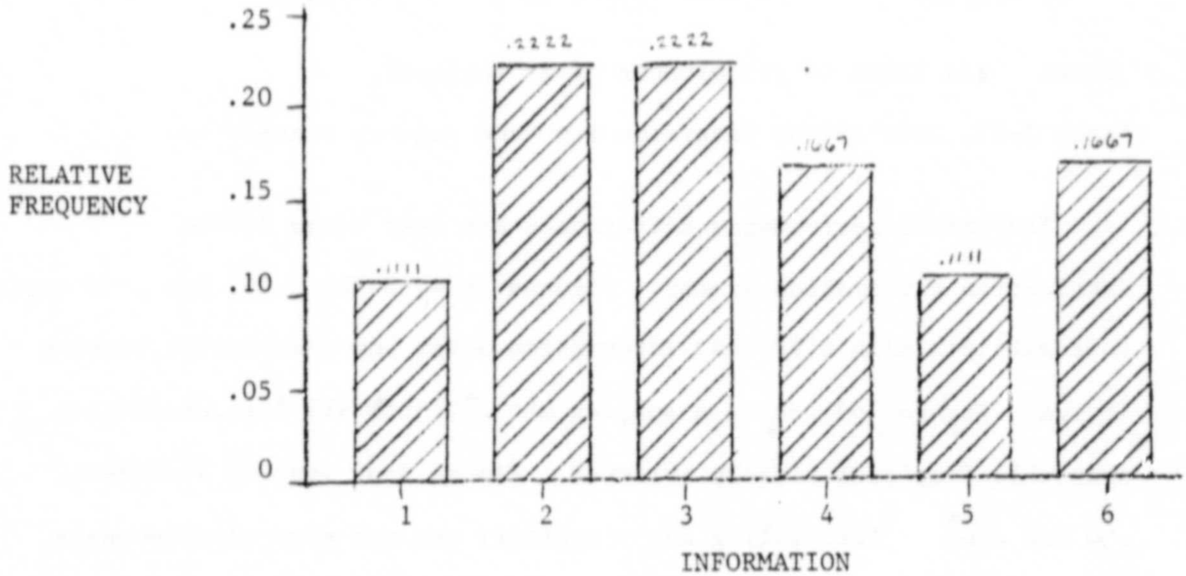
Airport #14



Airport #15



Airport #16



A statistical profile of the time and inquiry patterns of subjects is contained in Table 3-12. The items of note here are the wide variations in number of inquiries per subject and number of airports considered. A series of t-tests were run to distinguish the behavior of the professional versus the non-professional pilot. The only statistically significant result was that non-pro pilots required a longer average time to choose an airport once their data gathering was complete.

ITEM	MEAN	RANGE	VARIANCE
Inquiries Per Subject	22	6-44	84.8571
Airports Per Subject	6.28	2-15	9.2069
Information Per Airport	3.82	2-6	1.4292
Time Per Inquiry	3.44 sec.	2.15-5.88	1.1442
Time To Choose Airport	14.02 sec.	6-26.5	21.7067
Time Per Airport	27.39 sec.	13.11-52.33	89.2388

Note: Data based on performance of 29 subjects.

Table 3-12. Destination Diversion Time and Inquiry Statistics

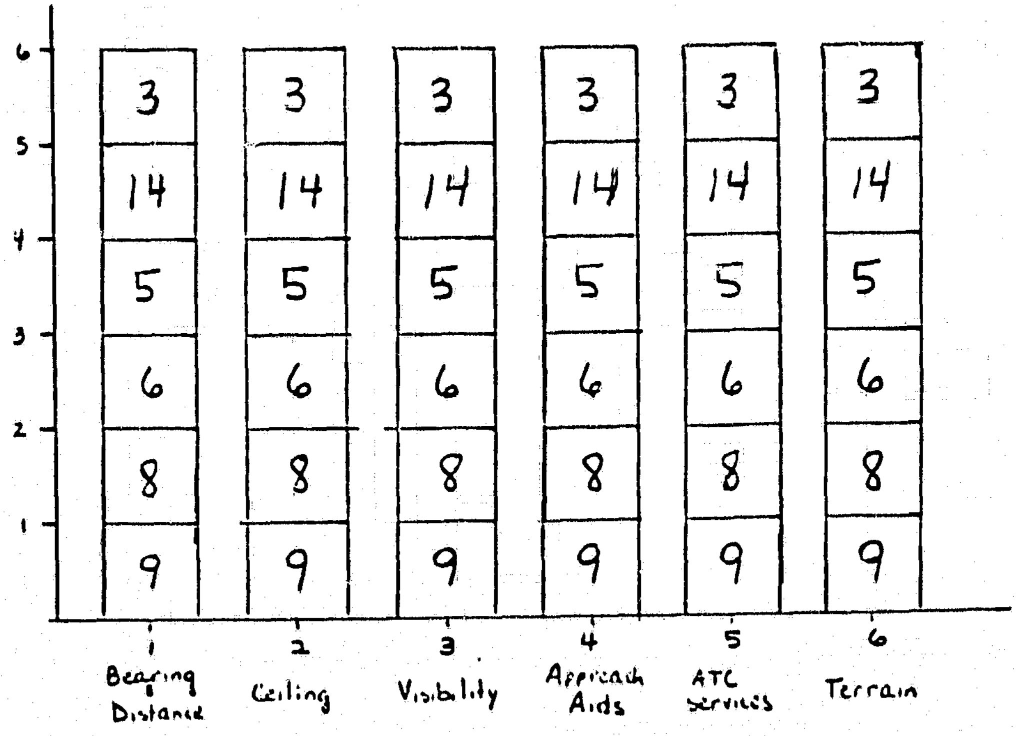
Individual performance differences are best noted in the destination information graphs. Figures 3-34, 3-35, 3-36, and 3-37 depict four subjects with different information needs and information seeking styles. Figure 3-34 shows a subject who collects all the information available from each airport selected. Figure 3-35 depicts a subject who has concern for ceiling and visibility but not much consciousness about terrain and other attributes. Figure 3-36 depicts a subject who

chooses an airport as soon as it meets his criteria and fails to use available time to locate "better" diversion airports. Figure 3-37 depicts a subject who first focuses on approach aids and only seeks added data on those meeting his approach aid criteria. The secondary information he seeks includes ceiling and visibility.

These DIGs are merely representative of the general styles of information search exhibited. Although each subject can be categorized into one such pattern, there is no discernible relationship between the way subjects collect information for diagnosis as illustrated by PIPs and the way they collect information in destination diversion decisions as depicted by DIGs.

Subject #51
Time Lapsed: 174
Sec./Port Selection: 10.625
Sec./Inquiry: 2.78
Airport Selected: #3
Note Nos. in the box refer to a specific airport

FREQUENCY OF ATTRIBUTE INFORMATION SOUGHT



ATTRIBUTE INFORMATION

Figure 3-34: Destination-Diversion Total Information Search

Subject #78
Time Lapsed: 189 sec.
Sec./Port Selection: 10.55
Sec./Inquiry: 3.0417
Airport Selected: #3
Note Nos. in the box refer to a specific airport

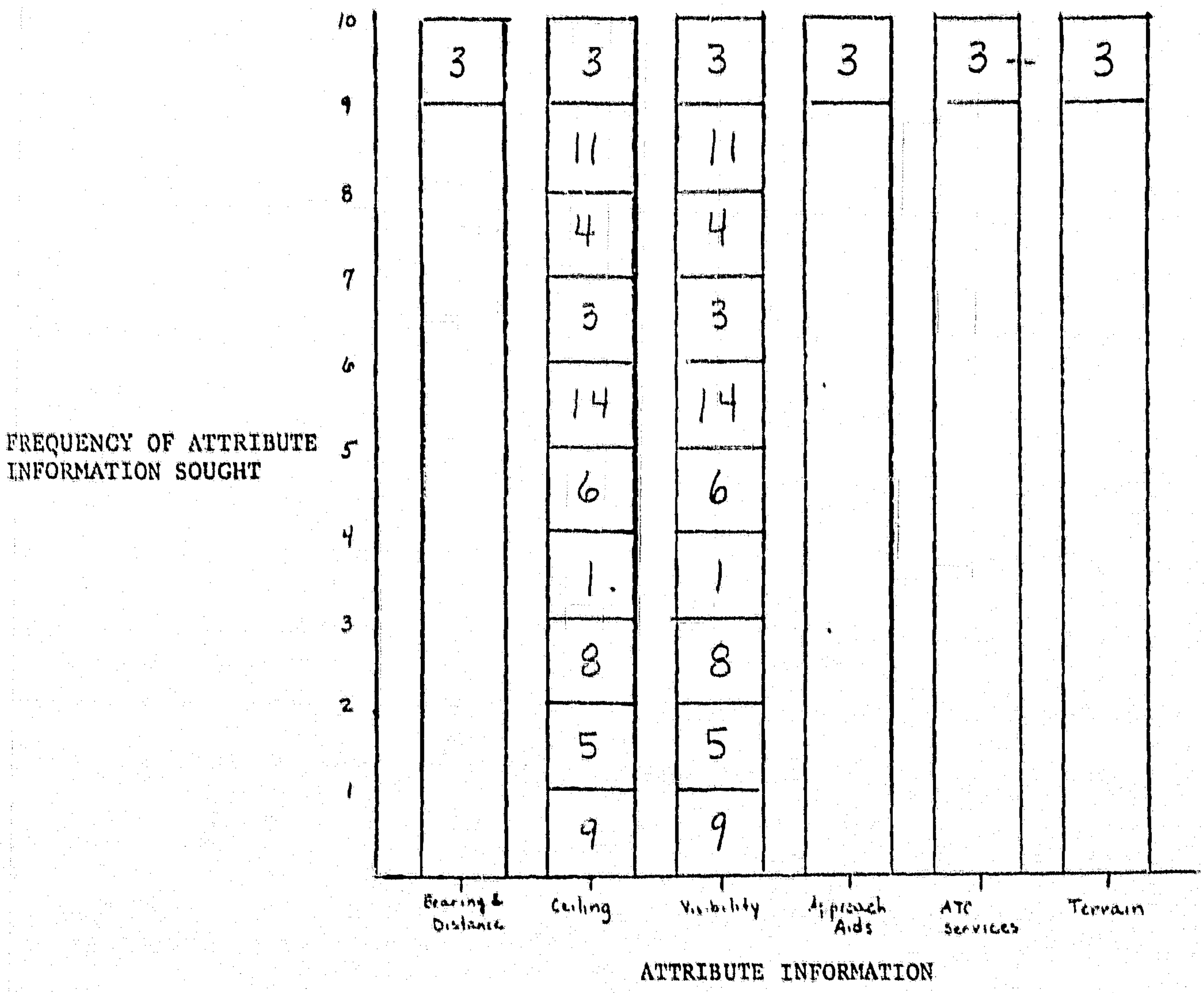


Figure 3-35: Destination Diversion Limited Information Focus

Subject #70
Time Lapsed: 78 sec.
Sec./Port Selection: 9
Sec./Inquiry: 5.45
Airport Selected: #1
Note Nos. in the box refer to a specific airport

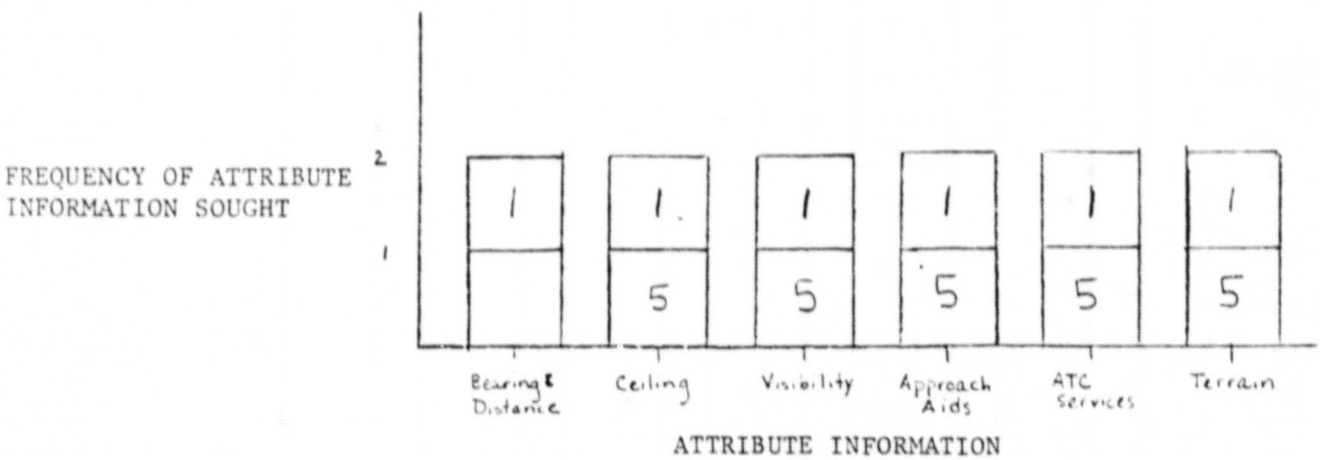


Figure 3-36: Destination Diversion Quick Decision

Subject: #54
Time Lapsed: 129 sec.
Sec./Port Selection: 9.625
Sec./Inquiry: 3.25
Airport Selected: #3
Note Nos. in the box refer to a specific airport

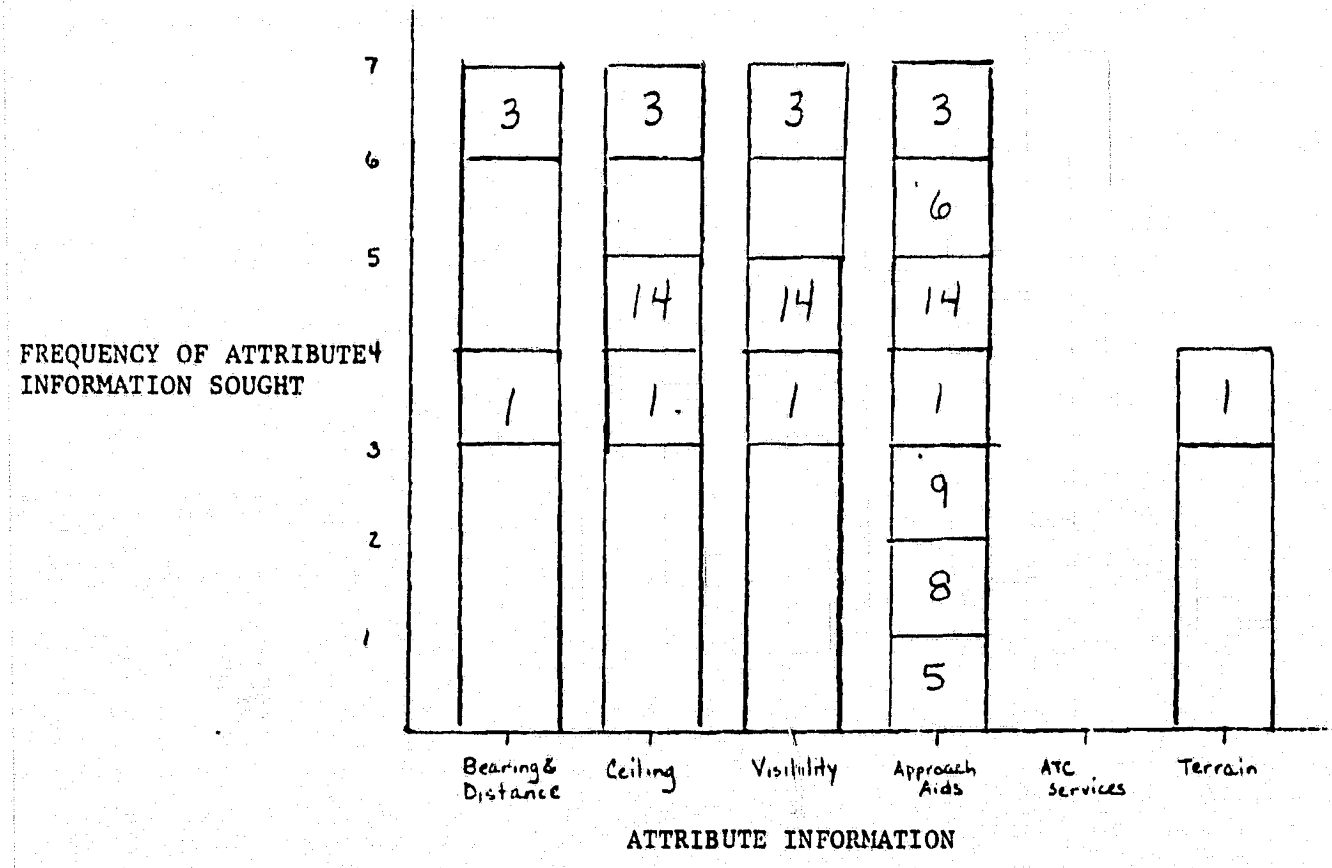


Figure 3-37: Destination Diversion Primary Criterion Search

H. An Experiment Combining Diagnosis and Destination Diversion Decisions Within Computer Aided Testing

Task 6 of the research plan called for an experiment combining the diagnostic and destination decisions within the computer aided tests. This required a simulated full mission scenario which embodied not only a CIFE but also navigational and communication inputs from the subject pilot. This necessitated rather sophisticated programs for the PLATO® system. For navigational responses the aircraft had to be located in space using VOR fixes and the computer had to account for heading and altitude changes imparted by the pilot through an auto pilot display. The navigational and autopilot display is shown in Figure 3-38. The pilot was given a simulated low altitude chart to locate his position relative to VOR's and available diversion airports (see Figure 3-39).

Communication using CAT is difficult because it limits the number of messages the pilot can communicate if one wishes to keep a menu driven display system and not require complex typed responses by the subject pilot.

Communication from ATC to the pilot is less a problem because alpha numeric messages to the pilot are relatively easy to present given that the computer recognizes the pilot's position within the flight. Figure 3-40 depicts the means by which the pilot communicates with ATC. This display is more involved than the ATC information display used in the simple diagnostic tests. The display permits the pilot to ask for information and also to give position reports and declare emergencies or request special handling.

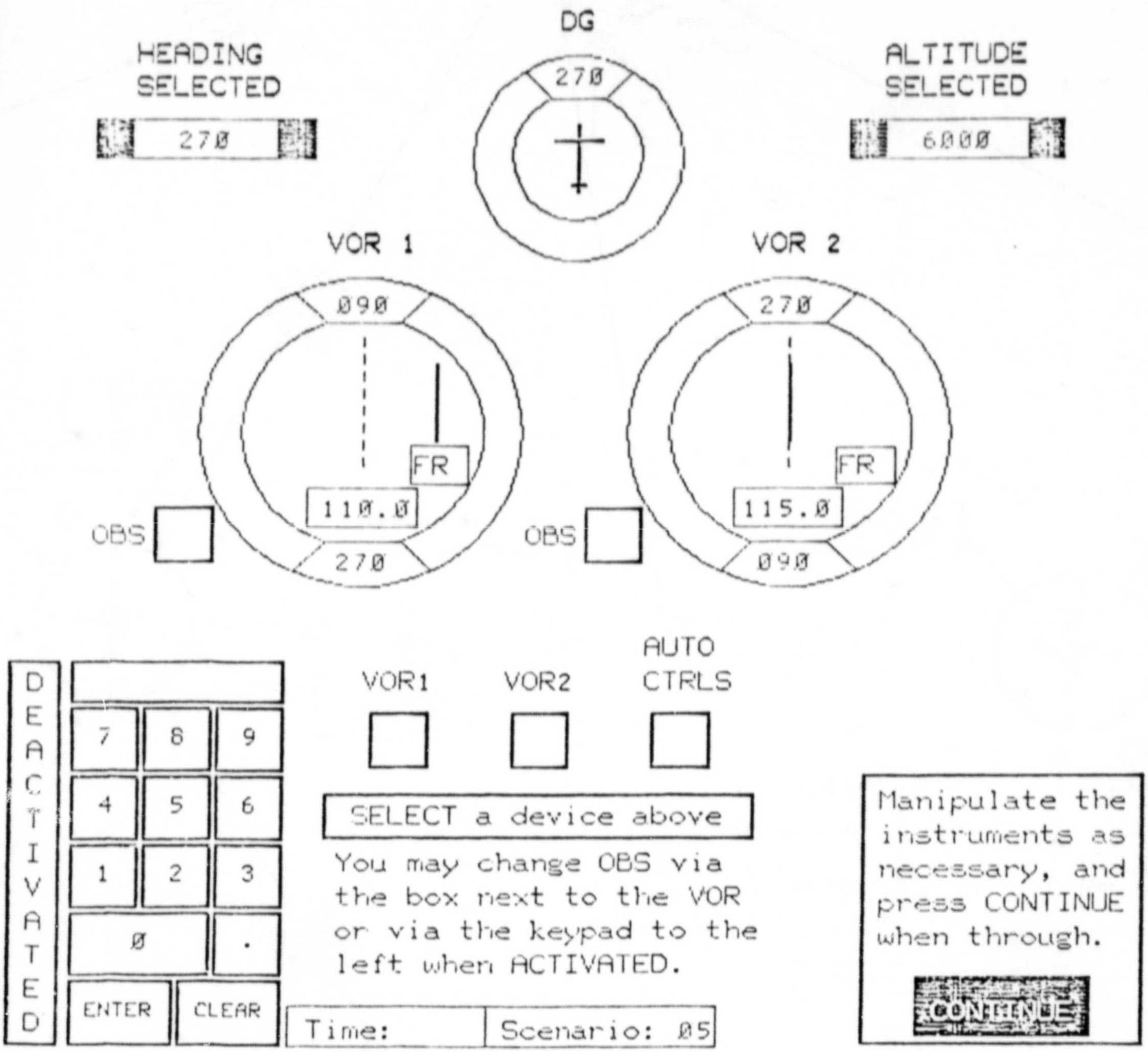


Figure 3-38: VOR-AUTO PILOT DISPLAY

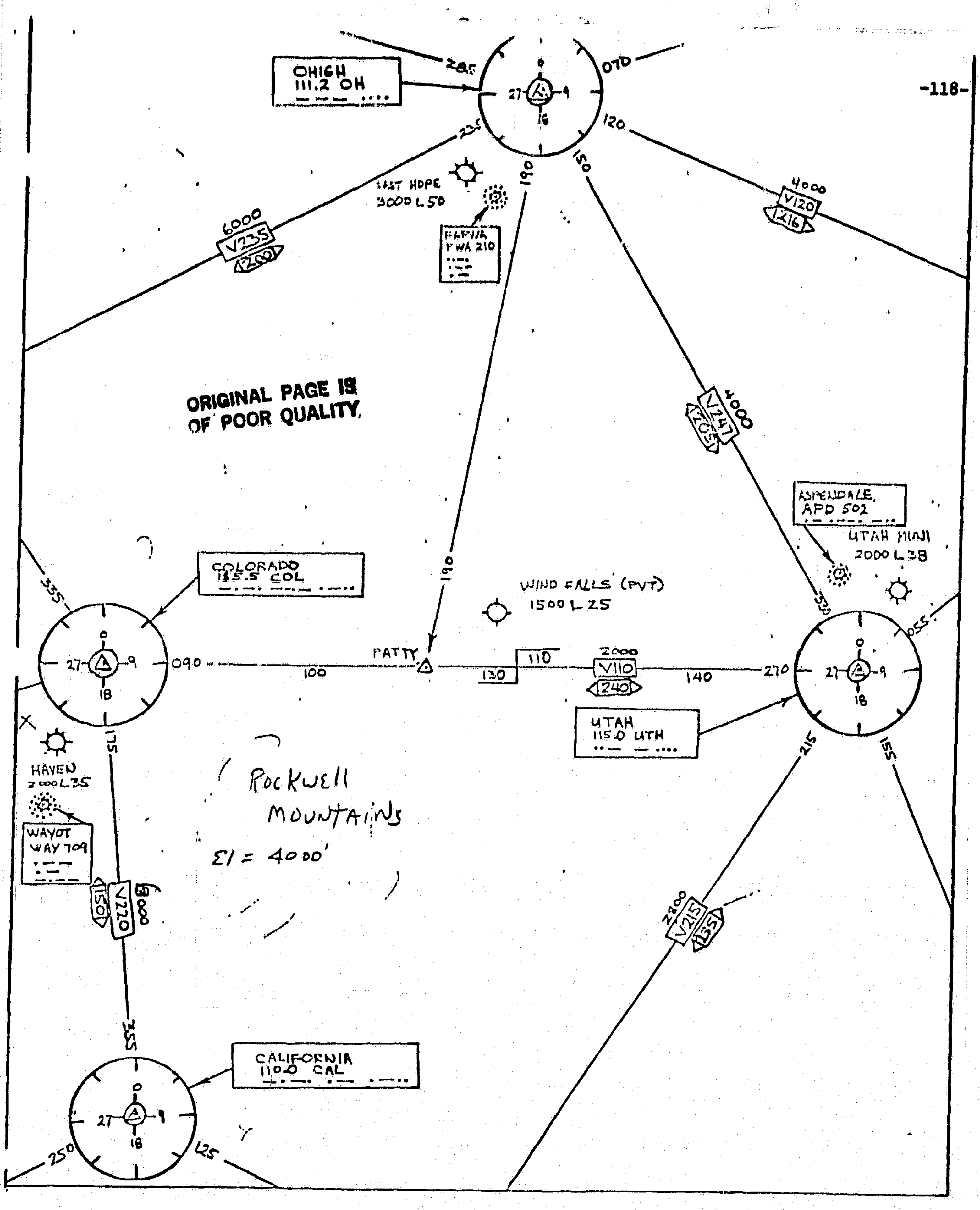


Figure 3-39: SIMULATED LOW ALTITUDE CHART

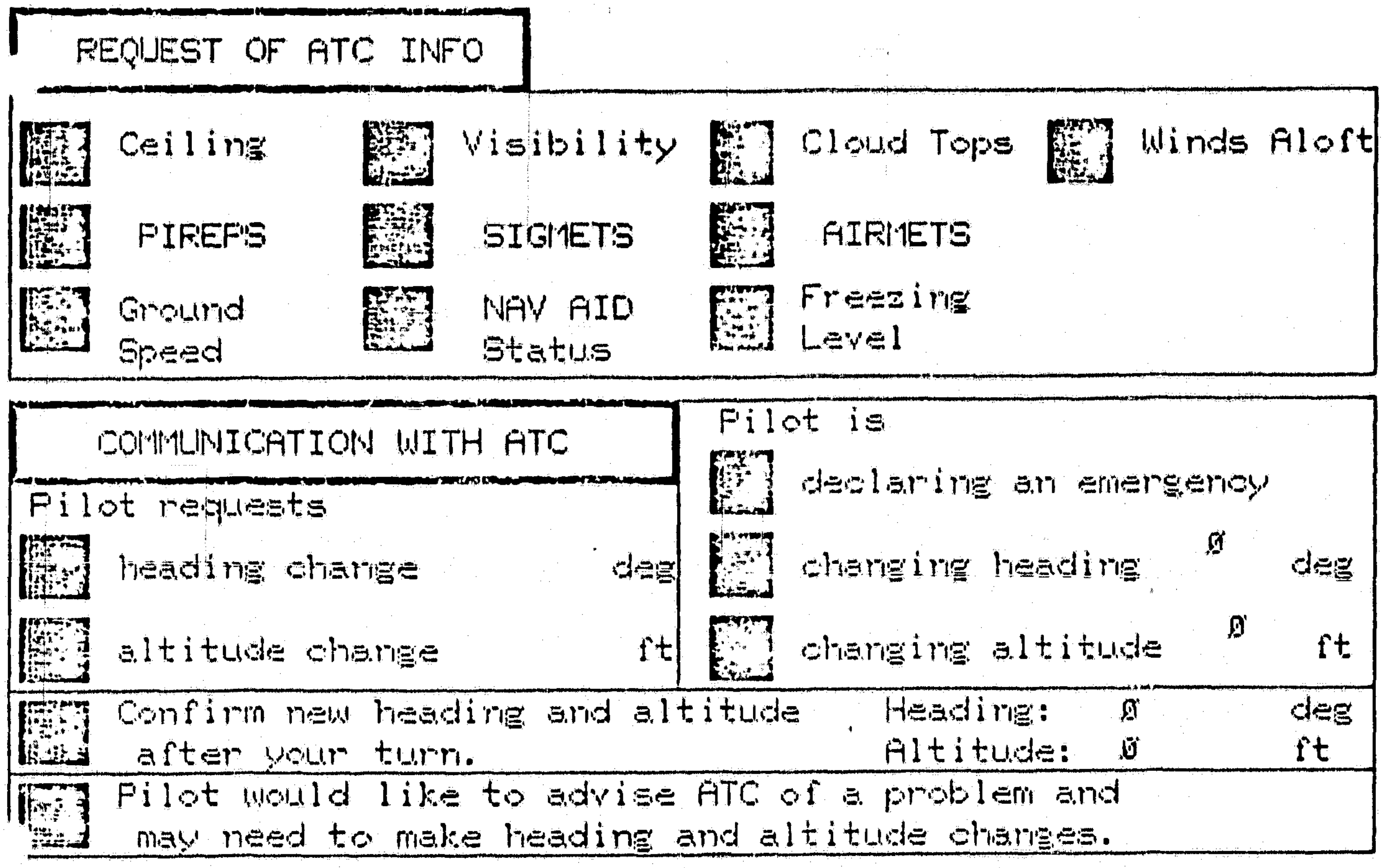


Figure 3-40: ATC COMMUNICATION DISPLAY

The scenario used in this experiment is a modification of scenario 5 described in Chapter 2. Essentially, it was decided to give the pilot a problem which would not likely be solved within the time available. A broken baffle was selected to ultimately force the pilot to consider his decisions about selection of a destination airport.

The simulated full mission scenario located the pilot such that he was heading into the mountains with an unresolved problem, i.e. unable to get full power from the engine and required by ATC to maintain 5000 feet in IMC conditions. Figures 3-41 through 3-45 depict the typical development of the situation with ATC communication to enhance position awareness. Table 3-13 investigates some of the inquiries made by a pilot attempting to resolve the problem.

Results

Table 3-14 describes the various responses made by pilots using this "full mission scenario". The intent of this study was to force a choice dilemma situation, i.e. the pilot could elect to: (a) struggle on over the mountains with a sick engine hoping no other problems develop, (b) declare an emergency and seek to land the aircraft immediately in minimum VFR conditions at a nearby private airport, or (c) to return to the airport of origin where instrument aids would be available. It was also of interest to ascertain how long the pilot would attempt to diagnose his problem before accepting the fact that he would be unable to get full power from the engine.

DIAGNOSTIC SCENARIO TEST

We are now going to present to you some Critical In-Flight Events requiring your diagnosis of the problem.

Assume that you are flying a fuel-injected Cherokee Arrow (N123B) with the following performance specifications:

Cruise Speed = 135 KTAS (65% pwr. @ 7000 ft.)

Fuel Flow (65% pwr.) = 10 GPH

Usable Fuel Capacity = 48 gallons

Endurance = 4.8 hours (no reserve)

Range = 648 nautical miles, (no wind, no reserve)

Press CONTINUE when finished reading.

CONTINUE

Figure 3-41: SCENARIO INITIALIZATION

Consult attached simplified low altitude chart.

You are on an IFR flight from Utah Municipal Airport to Haven County Airport. You depart on V-110 at 6000ft in your Cherokee Arrow (N123B) which is equipped with a 3-axis autopilot. There is a NOTAM out which reports that Colorado VOR is out of service during the period you plan to navigate. Navigate using Ohigh and California VORs. You have been enroute 60 minutes from Utah Municipal Airport. You are on the gauges but the ride is smooth. Weather briefing indicated that winds at 6000 were expected to be light and variable.

You have one passenger aboard.

Weather at:

Haven County Airport= 2000 & 5
Ohigh= 1000 & 3
Wind Falls= 1000 & 3 by a C-172
(10 minutes ago)

Cleve Center calls and reports radar contact is lost.
Please report present position.

CONTINUE	When ready, press the CONTINUE button to go to the VOR display to establish position.

Figure 3-42: SCENARIO SETTING

POSITION REPORT

Please report your position by pressing the TO or FR buttons for the VOR of your choice. (Choose at least two VORs).

Type in your position via the keyboard at the given arrow, then press the NEXT key to enter it.

California VOR	TO	40 ok	FR	
Utah MunAir VOR	TO		FR	260 ok
Ohigh VOR	TO		FR	

Press CONTINUE after you have made your report

CONTINUE

Figure 3-43: POSITION REPORTING

Last Clearance

ATC Response:

N123B, thanks for the position report.
Here is your new clearance:
proceed direct California VOR direct
Haven County Airport at 6000.

There will be opposite traffic
at 5000...maintain 6000.

Please confirm your new heading
and altitude after your turn.

Time: 7:32	Scenario: 05

Figure 3-44: ATC Response

SCENARIO CHANGE

While practicing hand flying with your autopilot disengaged, you notice that increased nose-up trim is required to maintain a constant indicated altitude and that your IAS has decreased 20kts. from normal cruise.

Your passenger notes this problem, and suggests that you turn back to Utah Municipal.

Determine the nature of the problem, and your destination decision.

Time:	Scenario: Ø5

VOR auto	ATC comm
Deci-sion	Init info
Last Clear	Ext info
	Instr Panel

Figure 3-45: INTRODUCTION OF THE CIFE INTO THE SCENARIO

DATANDISPLAYU E
##cife3 Diagnostic Scenario #05
##scene05

NAME:Estudent082
DATE: 07/30/82

TIME	TIME	DISPLAY	ITEM	CURRENT VALUE
0	10	Int info		
10	3	Int info	cargo cond	
13	4	Int info	door cond	
17	4	Int info	panel temp	
21	4	Int info	noise & vibration	
25	3	Int info	fluid leaks	
28	3	Int info	housekeeping	
31	2	Int info	smoke	
33	6	Int info	cabin temp	
39	3	Ext info		
42	4	Ext info	cowling	
46	2	Ext info	windscreen	
48	3	Ext info	wing	
51	2	Ext info	flap	
53	2	Ext info	aileron	
55	18	Ext info	stabilizer	
73	7	instr pan		
80	2	instr pan	pitot heat	
82	12	instr pan	pitot heat on	
94	17	instr pan	alt static	
111	18	instr pan	suction	
129	2	instr pan	pitot heat	
131	15	instr pan	pitot heat on	
146	13	instr pan	TACH	
159	14	instr pan	MP	
173	18	VOR-Auto		
191	55	Scenario		
246		GIVE ANSR		

Table 3-13: Illustrative Pilot Inquiries in the Combined Scenario

Early trials indicated a complete preoccupation with diagnosis and little position awareness. Attempts were made to increase position awareness through position reports to ATC and a passenger insisting they return to the origination airport. Despite these efforts, most pilots indicated little concern for altitude clearance violations and spent most of the time wrestling with the engine problem. Most opted to continue over the mountains without appraising ATC of the problem, though some pilots did declare emergencies or return to the airport of origin. Despite the fact that some pilots had experienced this engine problem earlier in diagnostic tests, there was little evidence that they recognized this problem or abandoned the diagnostic inquiries earlier than pilots viewing this problem for the first time. Table 3-14 shows that there is a considerable variation in diagnosis time, number of inquiries, and return to old track inquiries (DIFT). Only one pilot declared an emergency and none elected to put the aircraft down at the nearby private strip. Table 3-15 reflects performance differences of subjects who took scenario 5 as a pure diagnosis problem as compared to those who took it in conjunction with the destination diversion decision (denoted as P-G on PLATO® GAT). Again we see a wide variety of responses from both groups. The P-G group took more time on the first track and made more inquiries in general. This probably reflects the stress of the navigation decision.

The general conclusions from this experiment were:

(a) using CAT it is possible to provide realistic displays for navigation purposes;

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Subject #	76	77	78	79	80	81	82	83	84	MAX
Airport Selection	Haven	Haven	Utah Muni	Continue	Calif.	Calif.	Haven	Haven	Haven	
Time to Airport	0-30	>90	60-90	>90	60-90	60-90	30-60	30-60	>90	-
Alt. Changes	0	0	0	0	(Alt Hold) 3	0	0	0	0	3
ATC	0	0	9	0	0	0	0	0	1	9
Declared Emergency ?	N	N	Y	N	N	N	N	N	N	-
Diagnosis	Power Lost	Don't Know	Engine Temp High	Elevator Broken	Don't Know	Don't Know	Don't Know	Power	Gyro Failure	-
Diagnosis Time	237	436	650	0	647	204	246	404	324	650
Tot. Inq.	27	30	69	1	63	42	23	37	10	69
Total Tracks	9	17	25	1	24	25	12	19	5	25
Uniq. Tracks	6	7	8	1	7	8	7	9	4	9
DIFT	3	10	17	0	17	17	5	10	1	17
Inq/Track	3	1.76	2.76	1	2.625	1.68	1.92	1.95	2	3
Inq/Uniq. Track	4.5	4.286	8.625	1	9	2.47	3.286	4.111	2.5	9
Yoke Resp.	0	6	0	0	7	0	0	0	2	2

Table 3-14 Summary of Performance in Combined Scenario

Table 3-15 Tracks in Scenario 5 Alone and in Plato-Gat

Subject #	Scen 5 or Plato Gat	First Track	# Inq. on 1st Track	Time on 1st Track	2nd Track
56 IFR	5	Struct. Fail.	2	27	Other (gear)
57 IFR	5	Other (Suction)	1	13	Ice
58 IFR	5	Int. Enq. (MP)	1	16	Ice
59 IFR	5	Ice	1	16	Flight Status
60 VFR	5	Other (Cargo Cnd)	1	27	Struct. Fail.
61 VFR	5	Ice	4	31	Other (ceiling)
62 VFR	5	Other (Cargo Cnd)	2	41	Ice
63 VFR	5	Other (Cargo)	2	46	Struct. Fail.
64 VFR	5	Ice	2	26	Prop (TACH)
65 VFR	5	Int. Eng.	3	19	Fuel
66 VFR	5	Ice	3	26	Other (groundspeed)
67 VFR	5	Other (Cargo)	1	11	Prop (N&V)
68 VFR	5	Other (Suction)	1	7	Prop (TACH)
69 IFR	5	Other (Cargo)	1	-	Ice
70 IFR	5	Other (Gear)	2	59	Fuel (Throt.)
76 VFR	PG	Int. Eng.	5	49	Ice
77 VFR	PG	Struct. Fail.	3	44	Ice
78 IFR	PG	Flight Status	2	207	Other (Flaps)
79 IFR	PG	-	0	0	-
80 IFR	PG	Ice	4	31	Other (Suction)
81 VFR	PG	Fuel	4	26	Ice
82 VFR	PG	Other (Cargo)	3	27	Prop (N&V)
83 IFR	PG	Int. Eng.	3	24	Fuel
84 IFR	PG	ATC (DG HEAD)	2	211	Flight Status

(b) most pilots are reluctant to accept the fact that no diagnosis or solution is available in flight. This may result from the fact that all other scenarios presented had definitive solutions;

(c) diagnosis occupied the pilot's time much more than positional awareness;

(d) considerable variation in pilot response to this "full mission scenario" was apparent;

(e) no clear relationship between pilot information seeking and decision making and pilot experience and training was noted (probably due to the small sample sizes).

In effect, this experiment attempted to produce a GAT simulator experience using a computer terminal. Upon subject debriefing it was apparent the pilots were overloaded with information and reacted to the problem by treating the engine symptoms and navigation problems independently as opposed to an integration of diagnosis and diversion information. In their defense the subjects argued that in a real aircraft, positional (navigational) and engine information would be simultaneously available. They also argued that a one time presentation of this kind of scenario gave them little chance to adapt, i.e. they had little chance to do VOR tracking prior to the CIFE. Unfortunately, real CIFE's give pilots little chance to adapt.

There was insufficient time or funding available in the research program to pursue this "full mission scenario" using CAT beyond these exploratory experiments. It may be that trying to produce a type of GAT-1 simulator using computer displays is not an efficient or realistic approach.

Despite the question of whether this approach has value in understanding pilot logic structures, there appears to be considerable potential for pilot training.

I. Comparison of Computer Aided Testing With Paper and Pencil

The four basic diagnostic scenarios and the destination diversion scenario used in computer aided testing (CAT) were based on the same underlying problems as those used in earlier paper and pencil (P/P) experiments. The principal differences involved manner of presentation and timing. CAT was nearly experimenter free. Subjects received instructions and sought information from an interactive computer graphics display. The computer recorded the sequence of information exchanges and the time between inquiries. The P/P tests on the other hand required a verbal exchange between experimenter and subject to transfer information. Although the experimenter did record the order of inquiries, there was no provision for obtaining a complete time history.

Subject Characteristics

The sample sizes for CAT and P/P testing were nearly identical. CAT used 42 pilot subjects while P/P used 40. A quick comparison of the relative flying experience of the two groups can be seen in Figure 3-46, 3-47, and 3-48. Their relative performance on the knowledge test is shown in Figure 3-49. Both groups had identical questions on the knowledge test instrument.

The general impression is that the CAT test group is less experienced. The CAT group has more private pilots, lower total flying time and lower single engine time than the P/P test group. The entire group of P/P subjects hold the instrument rating while sixteen pilots in the CAT group are not instrument rated. The P/P group scored slightly higher in the knowledge test. These characteristics are summarized in Table 3-16.

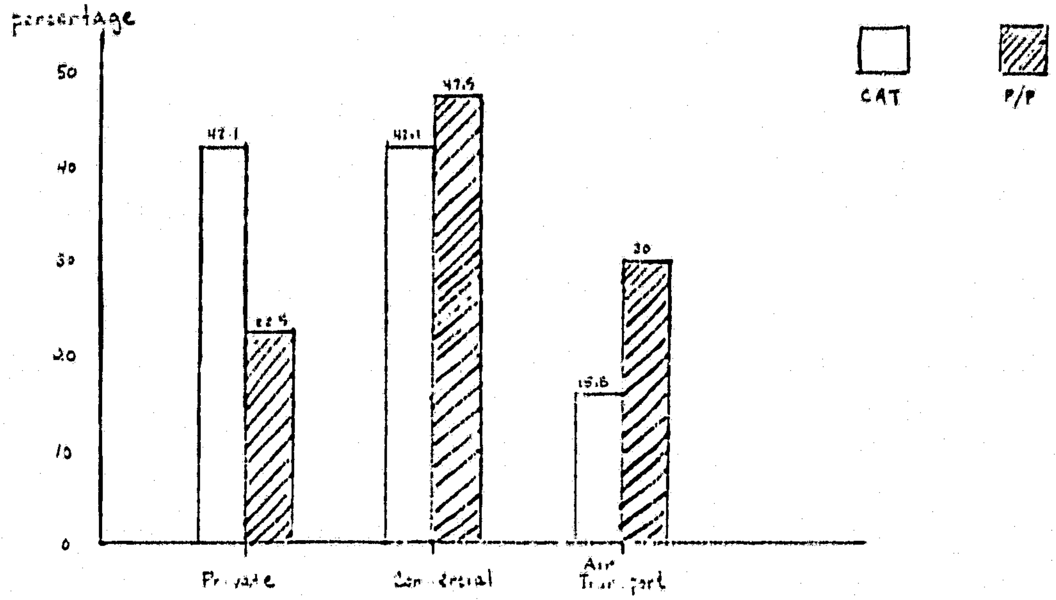

Figure 3-46: Certificates Held By Subjects, P/P versus CAT

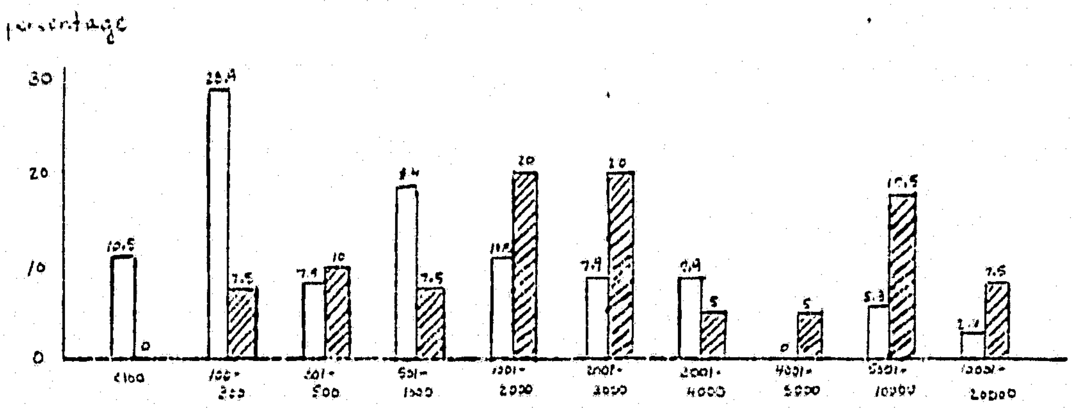

Figure 3-47: Total Flying Time By Subjects, P/P versus CAT

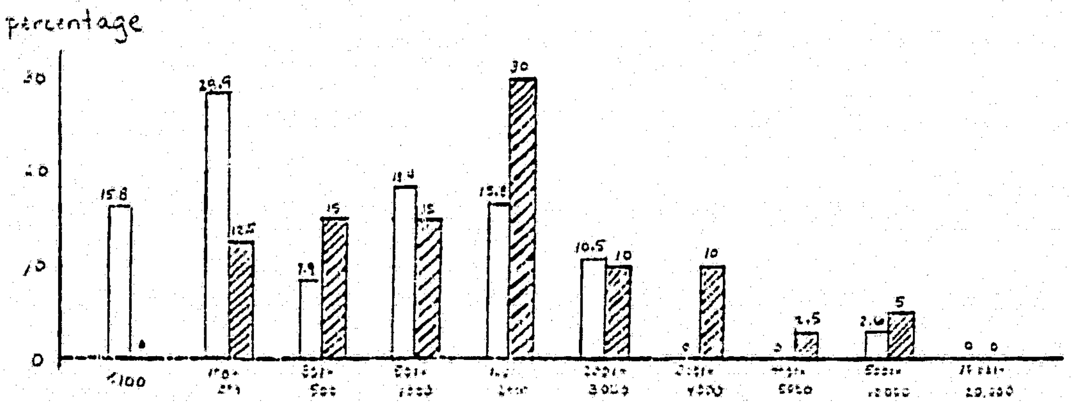

Figure 3-48: Single Engine Flying Time By Subjects, P/P versus CAT

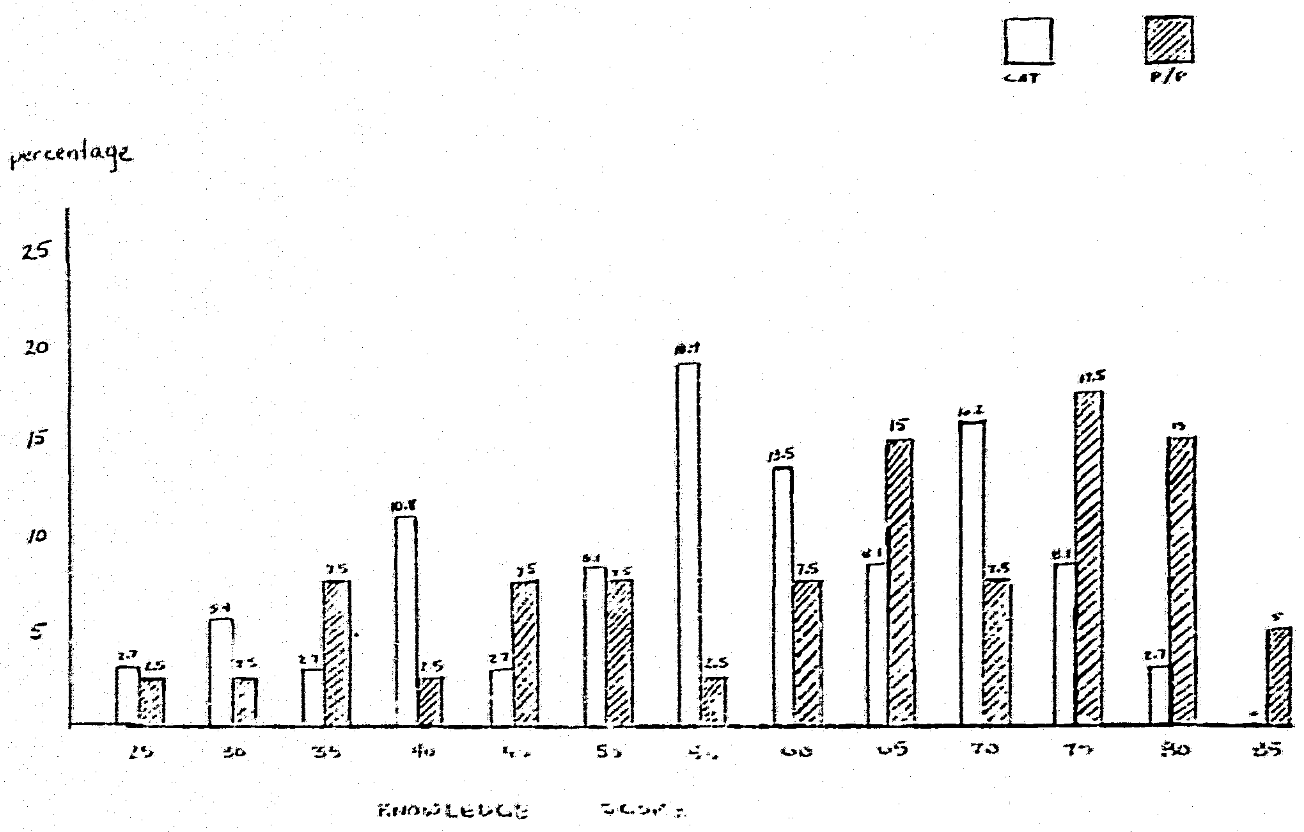

Figure 3-49: Knowledge Scores By Subjects, P/P versus CAT

	SUBJECTS	RATINGS (%) PVT	COMM	ATP	AVG TT	AVG SET	KNOWLEDGE TEST (%)
CAT	42	42	42	16	1654	933	57
P/P	40	22	48	30	3821	1911	62

Table 3-16. CAT and P/P Group Characteristics

Diagnostic Performance

Correctness scores for each of the four basic scenarios were based on five points for a perfect answer. However, the grading mechanism did change slightly between the P/P and CAT experiments. For that reason the relative differences among scenarios may be more significant than raw score differences between test groups. The average scores are depicted in Table 3-17. It should be noted that all P/P subjects took every scenario while not all of the CAT subjects did. Consequently, adding average scenario scores for CAT will not yield the total average shown.

	AVG. PERCENT TOTAL CORRECT	Average Scenarios Correctness Scores SCENARIO 1	SCENARIO 2	SCENARIO 3	SCENARIO 4
CAT	47	3.3	1.5	3.3	3.0
P/P	65	2.7	2.9	3.4	4.0

Table 3-17. Correctness Score Comparison

The higher average score for the P/P group is indicative of the generally higher level of flying experience of that group compared to the CAT group. An interesting finding occurs in the relative rank of scenario 2 scores. Scenario 2 involves a vacuum pump failure and subsequent loss of gyro instruments. The P/P group scored relatively higher on that scenario than did their CAT counterparts. Since the CAT group contains a number of non-instrument rated pilots, this result may suggest that pilots who must routinely

depend on their gyros are more cognizant of unusual indications. Table 3-18 compares general search patterns between the two experiments. The interesting thing here is that, with the exception of scenario 1, the P/P group made far fewer inquiries per scenario than did the CAT group. As one might expect, the CAT group also explored a higher number of tracks. This may suggest that the computer aided testing is more "user friendly" and invites a broader search for alternatives than does the verbal exchange in a paper and pencil format. One might also speculate that computer users are less inhibited about asking for what may be frivolous information than are their verbal counterparts who risk sounding foolish to the human experimenter who must respond to their questions.

Regression analyses performed on CAT scores reveal that knowledge subscores and source of flight training are predictors for correctness scores on some scenarios. These results are consistent with regression analyses performed on the P/P data. The only striking difference between the groups is that correctness scores by scenario seem to be related for selected pairs among CAT subjects while in no case is a good score on scenario i a predictor of score on scenario j in the case of the P/P subjects.

When subjects are split into high and low groups for t-test comparisons, results of CAT and P/P tests are similar. For example, in both cases subjects with high knowledge test scores tended to achieve high correctness scores and they were also the pilots with the most single engine flying time. Since most of these tests are based on the same biographical data and knowledge test scores,

	CAT	P/P
TOTINQ1	6.12	6.38
TOTRAK1	3.33	1.80
UNTRAK1	2.57	1.50
TOTINQ2	15.21	8.58
TOTRAK2	6.76	3.75
UNTRAK2	3.57	2.75
TOTINQ3	15.10	9.58
TOTRAK3	7.14	3.85
UNTRAK3	4.00	3.15
TOTINQ4	13.90	9.12
TOTRAK4	5.76	4.10
UNTRAK4	3.34	3.35

Table 3-18: DIAGNOSTIC INFORMATION SEARCH MEAN VALUES

the lack of glaring differences offers evidence that CAT and P/P testing are similar in performance measures expected from any given class of subjects.

Destination Diversion Performance

The difference in the mechanics of information exchange between CAT and P/P testing is again reflected in the inquiry statistics for the destination diversion scenario. The average number of inquiries is 22 for CAT versus 17.2 for P/P subjects. The information requests per airport shows a similar trend with averages of 3.82 versus 2.60 for CAT and P/P, respectively. The interactive terminal either invites a wider search or makes the information exchange more efficient thus permitting more inquiries in a fixed test period.

The general pattern of airport consideration between the groups is similar in that the frequency of consideration for a given airport decreases for airports further away. Both CAT and P/P subjects showed heavy interest in airport 5. However, the final choice of a destination diversion airport is completely different. The highest ranking airport among the P/P subjects was airport 14 while the CAT subjects preferred airport 3. Both choices have similar facilities (i.e. VOR approach and a tower) and both are in the same general direction. They differ in that 3 is in hilly terrain while 14 is in the mountains. The final choice may have been more influenced by the form of the map than by any real difference in preference between the groups.

The relative frequencies of type of information requested are quite similar for both groups. Ceiling, visibility and approach

aids are the most often requested information items. The medium of presentation does not generally appear to affect preferences for type of data in the destination diversion problem. There is one unexplained anomaly, however. Bearing and distance information represents 14.4 percent of the total information requests from CAT subjects and only eight percent from P/P subjects. It is not clear why this data should be a sizeable portion for either group since it can be at least roughly estimated simply by glancing at the enroute chart without wasting time on an information query.

Chapter IV: Learning In Computer Aided Testing of CIFE Diagnosis

Task 7 of the research was directed to subjects learning in terms of performance changes both within test sessions and across test sessions. The significance of this task can be better appreciated when one considers the long range potential of incorporating CAT in pilot training. Self-paced training would enable pilots to proceed through scenarios of increasing difficulty until some level of competency was accomplished.

Because of the novelty effect in using touch CRT's there was a need to see if pilot performance in terms of correct diagnosis, efficiency in arriving at diagnosis, and information seeking style would change within a test session and across test sessions. Insufficient time prevented across test learning experiments.

Within Session Learning

In order to test for order effects and not confound scenario difficulty with order, two order sequences were used. One group of subjects received scenarios 1, 2, 3, and 4, in that order. A second group were tested in the order 2, 3, 4, 1. Measures of performance included:

(a) the total number of inquiries

(b) the total number of tracks

(c) correctness score

(d) the time interval between inquiries (mean and σ^2)

(e) the number of unique tracks

(f) the total time to complete the diagnosis

In order to evaluate aggregate learning on performance scores it was first necessary to normalize subject data. Data for each subject was normalized by taking the average score across the scenarios

for each subject and then dividing individual performance measure by the average to get percentages. For example, for a given subject, correctness score on a given scenario would be some percentage of his average correctness score on all scenarios. This technique enables subject data to be added without giving heavy weighting to subjects with large numerical scores.

Table 4-1 shows a two way ANOVA - scenario vs. order for three scenarios (2, 3, and 4) and two orders (1,2,3,4, vs. 2,3,4,1). Note that for most performance measures the order of testing had no effect. As might be expected, scenarios were somewhat different in terms of correctness, number of inquiries, number of tracks, and number of unique tracks. It was generally found that scenario #2, the vacuum problem was the most difficult scenario for the subjects.

When time data is examined, means of time between inquiries (delta time) show a pronounced trial effect, i.e. the first trial (for both orders) is higher than all the remaining trials. Figure 4-1 separates IFR and VFR pilots for each order and depicts changes in mean delta times over the trials. The reason IFR and VFR pilots were separated was because of possible confounding effects. VFR pilots are over-represented in the order 2-3-4-1. With the IFR-VFR break out it is still clear that learning takes place across trials within each order in terms of time between inquiries. Beyond that finding, little learning is evident across trials within an order. This is an interesting and reasonable finding. Reduction in delta times comes with familiarity in using PLATO®. Diagnostic performance should be dictated by scenario difficulty and not by order of testing. From Figure 4-1 it appears that learning in terms of delta time would continue beyond the four scenarios tested.

Depend. Var.	Source	F Value	Pr > F	Signif.?
Correctness	Order Scen	.01 2.20	9129 .1175	No No
# of Inquiries	Order Scen	.45 2.08	.5059 .1313	No No
# of Tracks	Order Scen	.26 3.08	.6093 .0513	No Yes
# of Uniq. Tracks	Order Scen	.26 5.44	.6090 .0061	No Yes
DIFT (# Tracks - # Uniq. Tracks)	Order Scen	.07 .47	.7896 .6293	No No

Table 4-1 Order & Scenario Effects on Performance

Mean of the delta times

	A 1,2,3,4 IFR N=10	B 2,3,4,1 IFR N=2	C 1,2,3,4 IFR N=5	D 2,3,4,1 IFR N=9
Scen 1	136.833	45.575	113.070	78.445
Scen 2	110.656	200.615	105.160	130.714
Scen 3	83.234	89.875	78.316	99.114
Scen 4	66.692	63.945	85.052	89.346

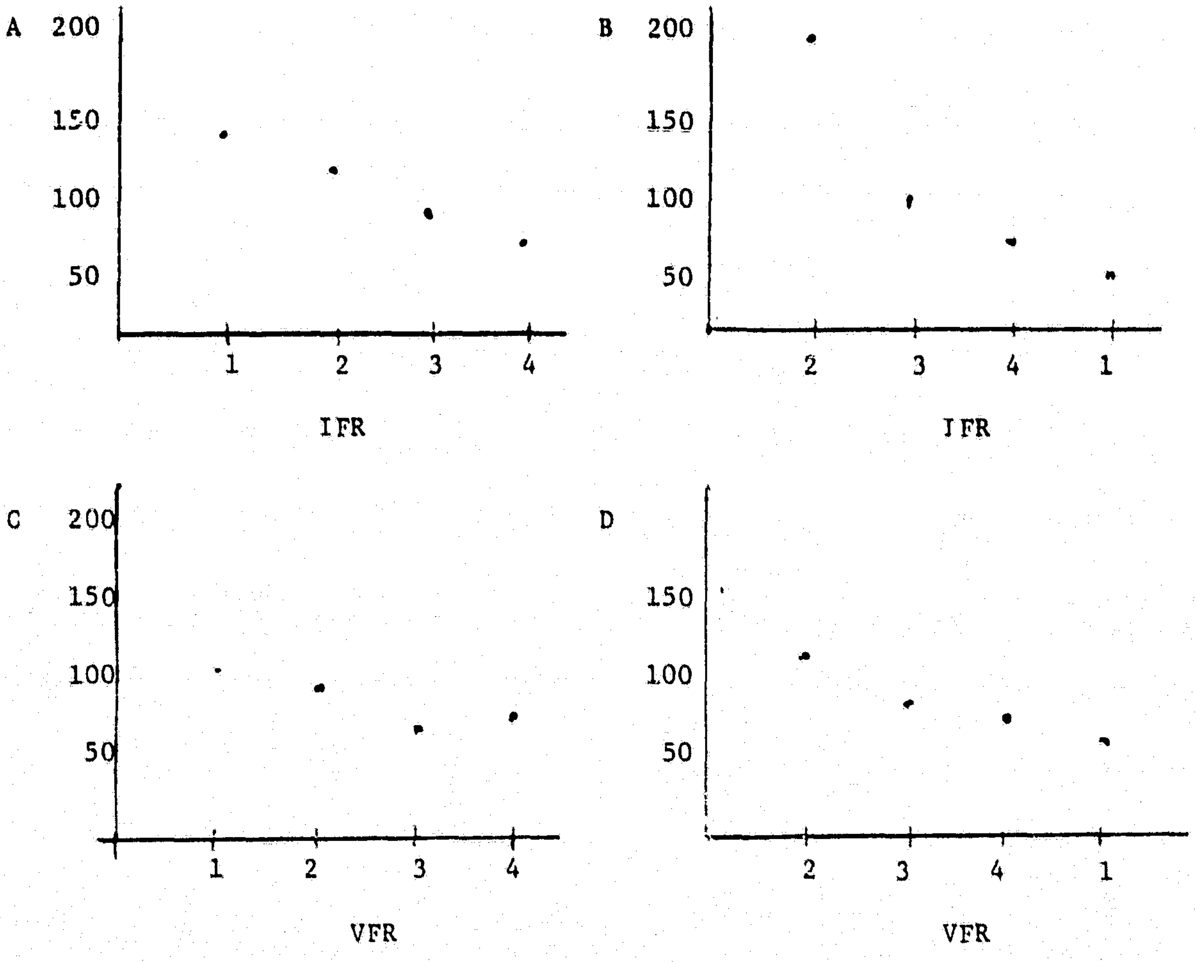

Figure 4-1 Changes in mean delta times by type of rating and order of scenario testing

To test for a confounding of rating with order, contingency tests were executed in a two by two design (two orders and two ratings - VFR/IFR) for the various performance measures. In all cases the hypotheses of independence were rejected at the ten percent significance level.

Chapter V: Computer Aided Programming

A wide variety of information search patterns were exhibited by subjects during CIFE diagnoses, some of which were more logical and efficient than others. In an attempt to streamline search patterns, preliminary investigation of the use of a diagnostic computer aid was carried out. A prototype Decision Support System (DSS) to aid a pilot in his decision making during an emergency situation was designed. The suggested model, called the Airplane Condition Evaluation (ACE), was patterned after MYCIN, a diagnostic computer aid used by physicians in their diagnosis of blood diseases.

ACE uses an interactive program similar to MYCIN which utilizes production rules and allows the user to input the current facts of the situation. Each of these production rules contains a small amount of information for ACE to draw upon. ACE is able to "reason" with current facts and to "deduce" a conclusion by joining together a series of these production rules. The production rules are modular and may be joined together in any way that the current facts support, thus allowing ACE to generate a diagnosis with any combination of aircraft symptoms. This system is described in complete detail in the MS thesis by Jeffrey A. Lee, A Decision Support System For In-Flight Emergencies: ACE (5). Mr. Lee is a Graduate Research Associate on the NAG 2-112 research project. A copy of that thesis has been submitted along with this report and is available at NASA Ames.

ACE is a "suggestion model" type of DSS which plays the role of a consultant with the expertise of an experienced aircraft pilot. It has the capability of accepting many variations of the problem it is geared for. Since it is computer driven, it has the advantage

of speed which makes it particularly well suited for a real-time environment. Such a system could be physically located in the cockpit of more sophisticated aircraft or located on the ground for use by smaller aircraft. In the ground mode some means of data exchange, perhaps as simple as voice radio communication, would be required. If the system was located at a Flight Service Station, for example, any flight service specialist could serve as a surrogate for the expert consultants currently available to air carrier and military. ACE would guide the questioning which the FSS specialist could relay to the pilot.

In its current state of development ACE contains a total of fifty-one production rules. These rules were distilled from a frequency count of information requested by PLATO® subjects who correctly diagnosed scenario problems and augmented by discussion with local "expert" pilots. The experts were used to establish the reason why information items requested with high frequency led to a correct diagnosis. The experts were able to suggest what could be inferred from a group of items of information and also what additional information would be needed to further support the line of reasoning. This analysis gave way to the formation of production rules and thereby established the expert knowledge and reasoning necessary to draw the correct diagnosis for a CIFE.

ACE has so far been constrained to the four scenarios developed in the earlier paper and pencil studies and later extended to the PLATO® tests. ACE does not yet have the ability to work in the real world but only in conjunction with this set of four scenarios and the corresponding set of information for each as presented by

the PLATO® data-gathering computer system developed for this research. Within those constraints, however, the 51 production rules contain enough expertise to correctly diagnose each of the four scenarios.

The following sample session with ACE illustrates a typical set of computer queries and subject responses. In testing ACE, responses were made consistent with data the subject obtained by querying the PLATO® representation of current aircraft status. Thus, two computer systems were used, a DEC 20 to house ACE and the CDC host computer which houses PLATO®. The accompanying logic trace shows the trees used in chaining to the recommended action or diagnosis.

The following is a sample session with ACE.

*** Welcome to ACE... the Airplane Condition Evaluator

ACE will try to diagnose a Critical In-Flight Event by
asking you a series of True/False questions. Please
answer each of the questions with a 'T' for a true
statement or an 'F' for a false statement. You may
also ask ACE why it is asking you a particular question
by entering 'WHY'. ACE will respond with the production
rule that it is currently considering to create
a probable diagnosis of the CIFE.

Please enter 'T' to start the questioning.
T

SUCTION LOW? (T/F)
WHY

*** HYPOTHESIS<1>
IF: VACUUM PROBLEM
OBV: SUCTION LOW
ACT: VACUUM FAILURE

SUCTION LOW? (T/F)
T

```
AS NOT CONSTANT? (T/F)
T

ALT NOT CONSTANT? (T/F)
T

(VSI NEGATIVE OR VSI POSITIVE)? (T/F)
T

AH LEVEL? (T/F)
T

DG CONSTANT? (T/F)
T

T/B SHOWING BANK? (T/F)
T

AIRPLANE CRUISING? (T/F)
T

AS INCREASING? (T/F)
T

ALT DECREASING? (T/F)
T


THE COMPUTED DIAGNOSIS IS THE FOLLOWING:

 -> VACUUM FAILURE


****************************************
DESIRE TRACE OF LOGIC? (T/F)
T

DESIRE TERSE TRACE? (T/F)
T

TREE<1>
IF: STOP
OBV: AIRPLANE CRUISING
OBV: AS INCREASING
OBV: ALT DECREASING
OBV: AH LEVEL
ACT: POSSIBLE VACUUM PROBLEM

TREE<13>
IF: POSSIBLE VACUUM PROBLEM
OBV: AS NOT CONSTANT
OBV: ALT NOT CONSTANT
```

```
OBV: (VSI NEGATIVE OR VSI POSITIVE)
OBV: AH LEVEL
OBV: DG CONSTANT
OBV: T/B SHOWING BANK
ACT: VACUUM PROBLEM

HYPOTHESIS<1>
IF: VACUUM PROBLEM
OBV: SUCTION LOW
ACT: VACUUM FAILURE

***********************************
DESIRE TRACE OF LOGIC? (T/F)
F

***********************************
ANOTHER CIFE? (T/F)
F
```

ACE's facility for showing the current rule that it is considering and its ability to show a trace of the rules it used to compute a diagnosis make the system more user friendly. A user sees not only where a current request for information came from but also may be reminded of possibilities that might not have occurred to him.

ACE is a prototype of a computer aid that may be useful in actual in-flight emergencies. It demonstrates that there is potential in the idea that a diagnostic computer aid can be built with production rules and be flexible enough to handle different scenarios and their individual sets of information.

Chapter VI: Summary and Conclusions

The tasks set forth in the proposal on the "Use of Computer-Aided Testing in the Investigation of Pilot Response to Critical In-Flight Events" have been accomplished. This project continued the early concern for the dynamics of CIFE's explored in the first report for NAS 2-10047 (6).

The products of the current research are 1) the First Symposium on Aviation Psychology held at Ohio State in 1981 (4); 2) a set of programs including new scenarios for computer aided testing (CAT) of subjects in CIFE's; 3) a dynamic system for CAT permitting combined diagnostic and destination diversion decisions (PLATO®-GAT); 4) a prototype Decision Support System to streamline search patterns (ACE); 5) a data base of responses from 40 pilots in the Columbus area (80 total when added to earlier paper and pencil subjects). By-products of this research so far have included one M.S. Thesis, two journal publications and a conference proceedings.

A. First Symposium on Aviation Psychology

The First Symposium on Aviation Psychology was held at Ohio State on April 21 and 22, 1981. The symposium was supported by this NASA grant. The objective of the symposium was to "critically examine the impact of high technology on the role, responsibility, authority and performance of human operators in modern aircraft and air traffic control systems." (4-i)

The attendee list for the symposium contained 210 persons from across the nation, many with outstanding credentials in aviation, engineering, or aviation psychology. Over 40 papers were presented at the symposium and published in the proceedings. In addition,

selected ones of these papers were published in the Journal of Aviation Space and Environmental Medicine. As a result of these efforts a second symposium has been scheduled for April 1983.

B. Computer Aid Testing Demonstration

The research team was successful in converting paper and pencil scenarios for diagnosis and destination diversion decisions into a computer interactive touch CRT system. This system provides the following advantages over the earlier paper and pencil studies.

1) The system is experimenter free, i.e. detailed instructions are given via the graphics display permitting subjects to run the system without the physical presence of an experimenter.

2) Subjects are enthusiastic about the presentation format. Their motivation remains high for test periods of up to 90 minutes long.

3) Subject response requires only a simple touch of the CRT screen. Keyboard entries are not required after initial sign-on.

4) Menu response formats reduce ambiguity and facilitate data analysis.

5) A complete catalog of pilot responses is available in the data display module.

6) A complete time history of pilot inquiries and responses is recorded.

7) National testing capability is present without moving experimenters or equipment. The many CDC Learning Centers throughout the U.S. as well as privately held PLATO® terminals can be used to call up and run the programs on site. Data files are maintained centrally.

From comments made by pilots who participated and from observations by the research team, it appears that computer aided testing (CAT) offers a realistic method to study pilot response to critical inflight events. In addition, CAT has the potential to become a valuable training aid.

C. The PLATO®-GAT System

The term "PLATO®-GAT was coined to describe the dynamic navigation and control system developed for computer aided testing. The task to be addressed was one of combined destination diversion and diagnosis decisions. The PLATO®-GAT system demonstrates the following capabilities:

1) The system provides an automatic tracking feature which permits the experimenter to place the subject aircraft anywhere in the simulated test area, then track the movement of the aircraft over time.

2) The pilot can determine his position in space by cross-checking on dual VOR indicators. The indicators are dynamic and show course deviations over time.

3) The pilot can alter his simulated heading and altitude by appropriate touch-panel entry on the auto-pilot display.

4) ATC position reports and clearances are part of the scenario.

5) The system combines in the touch CRT both the destination diversion decision and the problem of diagnosis.

The intent of PLATO®-GAT was to introduce a more realistic framework for tests which would begin to approach the fidelity of earlier GAT simulations. The dynamics associated with the decision making portion of a GAT-type simulation experiment were preserved without the accompanying stick and rudder manipulation. This was accomplished on a simple set of CRT displays.

D. Computer Aided Prompting

A prototype decision support system to aid pilots in decision making during emergency situations was developed. The model called Airplane Condition Evaluation (ACE) was patterned after MYSIN, a diagnostic computer aid used by physicians in the diagnosis of blood diseases.

ACE has the following characteristics:

1) It is an interactive program which permits user input on the

current facts of a situation.

2) ACE "reasons" with current facts to "deduce" a conclusion by joining together a series of production rules.

3) Although designed around the four basic CAT scenarios, ACE has the capability of accepting many variations of the problem it is geared for.

4) ACE is user friendly in that it shows the current rule being considered as well as a trace of the rules it used to complete a diagnosis.

E. Results from CAT

A series of correlation studies, stepwise regression analyses and t-tests were performed on the combination of pilot background variables, knowledge survey results, diagnostic scenario performance and decision making measures. Among the observations made from these analyses are the following:

1) Of the four basic diagnostic scenarios tested, pilots have the most difficulty in identifying the symptoms of a vacuum pump failure.

2) Pilots who score well in the knowledge test are good at diagnosing vacuum pump and static system failures.

3) Knowledge is inversely related to diagnostic inquiries, i.e. knowledgeable pilots reach conclusions (right or wrong) more rapidly than others.

4) Less experienced pilots tend to use a larger number of diagnostic tracks than do more experienced pilots.

5) Civilian trained pilots score higher on the vacuum pump failure diagnosis than do military trained pilots.

6) IFR rated airmen receive higher knowledge scores and higher diagnostic correctness scores than do VFR rated airmen.

7) High correctness scores are positively related to high mean time between inquiries, i.e. pilots who take time to absorb and manipulate current information before seeking new data are more apt to be successful than those who rapidly collect large amounts of disjoint information.

8) The data most often requested in diversion decisions are ceiling and visibility. Terrain receives a low number of inquiries.

9) Pilots often neglect winds aloft information in selecting an alternate airport.

10) There is no discernible statistical difference in the time or inquiry performance of professional and non-professional pilots in selection of alternate airports.

In addition to the more formal statistical comparisons, special graphical devices were used to analyze pilot performance. These devices were used to analyze pilot performance. These devices were the pilot information plots (PIP), schema diagrams, and destination graphs (DIG). Among the observations made from these analyses are the following:

1) Pilots follow a wide variety of different search patterns during diagnosis.

2) Pilots tend to exhibit similar search strategies across all scenarios, i.e. a pilot with a very systematic search pattern on any one scenario will behave similarly on all others.

3) Based on PIP and Schema Analyses, efficient information searching can be hypothesized. It appears that the ideal pilot should do the following:

   i) Confirm symptoms.

   ii) Establish engine health status.

   iii) Establish an hypothesis concerning cause.

   iv) Determine hypothesis plausibility with a minimum number of inquiries on an appropriate track.

   v) Given logical cause of the symptoms, test alternative hypotheses by additional information inquiries.

4) Schema diagrams are scenario dependent.

   i) In the oil leak scenario, the only distinguishing feature of correct versus incorrect groups is that the correct group focused on internal housekeeping questions while the incorrect did not.

   ii) In the vacuum pump failure scenario, the only common element between the correct and incorrect groups is a strong concern for icing indications. Only the correct group bothered to check gyro instruments.

iii) In the broken magneto scenario, the correct group checked the ignition system while the incorrect one did not.

iv) In the frozen static port scenario, both groups suspected ice, but the incorrect group abandoned that track early in the search.

5) Several general styles of information search strategy can be discerned from the DIG's.

6) There is no discernible relationship between the way a pilot collects information for diagnosis and the way he collects information for the destination diversion decision.

The order of scenario presentation was different for a subgroup of the CAT subjects. This was done to test for learning effects within the diagnostic test session.

The only discernible learning effect is with respect to time between inquiries. The first trial in CAT for both orders of presentation has a higher mean time between inquiries than all subsequent trials. The reduction in inquiry time apparently comes with familiarity in using the touch CRT system. The responses of pilots are essentially scenario dependent. Number of inquiries, number of tracks and number of inquiries per track all depend more on the content of the scenario in question than on its order position within test session.

Four subjects were re-tested on scenario two (vacuum pump failure) several months after their first exposure to that scenario. Correctness scores and track performance showed little change. However, the mean and variance of time between inquiries were lower for the second trial.

Although the data samples are small, the evidence indicates that learning in terms of timing of inquiries does take place both within and across scenarios. Other performance measures do not seem to be affected. This suggests that information seeking style is governed

more by scenario content than by experience with CAT gleaned from past scenarios.

In general CAT appears to offer the most potential for learning how to attack particular families of CIFE's. In addition it can be used to show pilot deficiencies in understanding the nature of CIFE's.

F. <u>CAT versus Paper and Pencil</u>

If one is careful to account for the differences in experience levels of the two groups of subjects, the results of the CAT experiments are generally consistent with those reported in the 1981 report on paper and pencil testing. Among the few differences noted are the following:

1) The P/P group made fewer inquiries and explored fewer tracks in diagnosis than did the CAT group. This suggests that the computer form of testing may be less inhibiting and more user friendly than face to face verbal exchange.

2) The CAT group performed a wider search for destination information than did the P/P group.

3) Although the most frequently selected airports were different between the groups, the physical characteristics of the most popular airports were similar in both cases.

G. <u>PLATO-GAT Highlights</u>

The PLATO-GAT experiments attempted to produce a GAT simulator experience using a computer terminal, in so far as resource management and information seeking were concerned. Both diagnosis and destination diversion scenarios were combined. This required the subject to diagnose a problem while enroute in a dynamic simulated environment in which alternate destinations could be selected.

General observations about PLATO-GAT include the following:

1) Pilots exhibit a wide variety of resource management styles similar to those found in the full mission simulation GAT studies reported in 1981 (6).

2) Pilots show a strong preoccupation with problem symptoms and corrections which lead to poor positional awareness and poor choice of destination airports. This characteristic was also noted in the full mission GAT studies.

3) Most pilots are reluctant to accept the fact that no diagnosis or solution may be available in flight.

4) Pilots do not appear to plan for problems in terms of constantly keeping enroute alternates in mind in case a problem does develop. Their management style is more reactive than pre-structured.

H. Training Potential

The computer aided testing instruments described in this report were developed as research tools to be used to better understand the decision making styles of pilots faced with critical in-flight events. However, from observations by the research team and from repeated comments by subject pilots, these tools may have even greater potential for pilot training.

CAT offers the possibility of self-paced instruction in acquiring basic aeronautical knowledge through an expanded version of the current knowledge survey. Such an expansion could easily include immediate feedback on the correctness of an answer, reasons for the correct response and references on availability of additional information. CAT also offers the opportunity to experience a variety of critical in-flight events from the safety of the computer terminal. In addition to a wealth of potential simulated decision experiences, CAT could be used to uncover pilot deficiencies in their current understanding of the nature of CIFE's and to train pilots to develop more efficient information search habits.

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